TIN MINING

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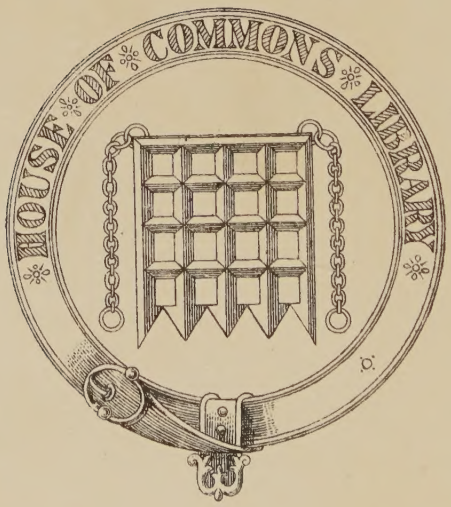

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TIN MINING

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A COMPLETE GUIDE FOR ALL ACTIVELY INTERESTED OR ENGAGED IN TIN MINING

BY

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INTRODUCTION

During the last quarter of a century a great deal of time has been given by scientists to the study of Economic Geology. Many publications have appeared in the English language devoted to the description of ore deposits in general, and each writer in turn has had the advantage of being able to consult the published works of others. Monographs on deposits of tin ore are particularly prolific, owing to the fact that the natural mode of occurrence of tin ore illustrates in an exemplary manner many of the principles and fundamental laws which govern the phenomena associated with other mineral deposits in Nature.

The appearance of another volume on the subject is appropriate at the present time. In the first place it deals with every phase of tin mining in a simple and practical manner. It is several years since a book has been published which pretends to cover the same ground. Its appearance is timely, for industry is trying to recover the ground lost by political dissensions and dislocations, and there are now signs of a revival in the mineral industry as a whole. New problems have to be faced by the mining engineer which have no direct connection with industrial conditions, and this book is designed to help the practical miner as well as those investing in tin-mining enterprises.

It will be readily granted that the industrial demand for tin will not diminish, but will almost certainly increase. On the other hand, the richest parts of several of the most productive deposits which have supplied the world in recent years are beginning to show signs of exhaustion, and new deposits will have to be found if the price of tin is to be maintained at a commercial level. There remain several large districts, as yet scarcely opened up, in which the occurrence of tin ore is reported by explorers, and the writer of this book has no doubt they will be developed in a few years. Their early exploitation must depend on local facilities for carrying on mining operations. Mining

is rightly left to the enterprise of private individuals. In the course of the struggle which must inevitably take place between them, the best or luckiest obtain the rewards of knowledge, personal ability, or pluck. Their success is beneficial to the industry at large, and the tribute which industry pays to ability in the shape of profits must not be grudged, for there are always risks attending new ventures, and the pioneers demand profits in a compensating degree. Many slogans have been heard lately, and though the word has become tarnished by too frequent misuse, the slogan for this book is " safety with profit." A pretty full account of the finances of flotation and maintenance of mining ventures is given towards the end of the book, while elsewhere the importance of thorough examination and testing is insisted on before embarking on costly outlay.

As regards the low-grade ore left in some of the old tin-mining areas, the question naturally arises as to whether they can still be worked profitably in view of rich new discoveries. It should be at once stated that the conditions for working low-grade ore are much more favourable in old established tin-mining areas than in newly discovered deposits. The truth of this is shown by the profitable extraction of mineral from the waste sands and other tailings left as unsightly heaps by the old generations of miners, and this is owing to the settled conditions of labour, water supply, and fuel when compared with new fields. Much depends on the absence of interference from politicians, for such low-grade propositions have no margin to spare for luxuries of this kind. A general lowering of prices for tin ore, owing to foreign competition, leads as a rule to the necessity of closing down low-grade propositions, for a time at least, an example of which was the failure of the Cornish mines in the seventies and eighties of last century, due to the large shipments of tin ore from Malay.

Perusal of the page of contents of this volume will reveal that the subject is dealt with in the natural order of thought in which a proposition would be approached. First, the nature and occurrence of tin ore, and then the methods of prospecting for it and testing its value. These descriptions are followed by chapters on the machinery

necessary for winning and dressing the ore according to the nature of the deposit (*a*) from underground mines, and (*b*) from alluvial deposits.

The volume concludes with chapters on the business (or financial) side of mining, and some general accounts of an economic and historical nature.

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TIN MINING

CHAPTER I

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Metallic tin has never been found in the native state in commercial quantities. The small discoveries that have been made from time to time are probably the residues of smelting operations, or they may have been due to the burning of peat containing alluvial cassiterite, or to the reduction of some of this mineral lying on the surface by " Bush " fires.

The commercial source of the metal is the mineral known as " cassiterite," the dioxide of tin.

Physical Characters of Cassiterite.

Colour. This is variable. The commonest colour is black. Next to this comes brown. " Ruby tin " is found in some districts, in others the colour may be an amber or a sulphur yellow. Cassiterite is also found grey, nearly white, and (very rarely) colourless. Black cassiterite is nearly opaque ; all other varieties are more or less transparent or translucent. In some districts several different coloured types occur together. The colours observed in the different varieties are supposed to be due to manganese and other impurities.

Lustre. This is vitreous or resinous, never metallic. " Amorphous," or non-crystalline, cassiterite has a dull or " earthy " lustre.

Specific Gravity. Its specific gravity (that is, its weight compared with an equal volume of water) is from 6·8 to 7·2, which is about three times that of the common rocks and stones.

Crystalline Form. Cassiterite is usually crystalline. The shape of the crystal is a tetragonal prism terminated by a tetragonal pyramid. The crystals vary much in size ; when they are very small it is necessary to use a good hand lens to distinguish their shape. The crystals may be short and squat, or long and thin ; the long type is known as " acicular," or " needle " tin. Large and very perfect crystals are sometimes found in lodes and in alluvial deposits ; but though such specimens serve well to illustrate the form of well-shaped crystals and are often exhibited in museum collections, they are not representative of cassiterite as *ordinarily* found. Cassiterite is also found in massive form, in which no crystalline form can be distinguished by the eye, and in a concretionary form, known as " wood " tin, from its fibrous appearance, and " toad's eye " tin from the concentric markings that it exhibits. These forms have little or no lustre, and are usually brown in colour.

Hardness of Cassiterite. When individual crystals are seen which are large enough to test with the blade of a knife, it will be found that they are too hard to scratch with a knife-point. Small crystals may be broken off from the rock that they are embedded in, and so seem to be softer than a knife blade. Wood tin and toad's eye tin are soft and brittle compared with crystallized tin, and can generally be scraped into powder with a knife-point.

Chemical Characters and Tests. The composition of cassiterite is dioxide of tin, with small quantities of impurities. When pure it contains 78·6 per cent of metallic tin. It is not soluble in water or in any acid. Heated alone before the blow-pipe it does not melt and is unchanged in composition. When powdered and mixed with charcoal and sodium carbonate, or mixed with potassium cyanide and heated before the blow-pipe, it is reduced to metal. The metal can be extended under the hammer, or cut by a knife, and it does not mark paper as a lead bead would. If the bead is warmed with nitric acid it is converted into metastannic acid, a white powder insoluble in acid and water. Cassiterite can also be reduced to metal by heating it to a higher temperature with powdered anthracite.

As cassiterite is insoluble in acids there is no convenient

means of testing raw material by chemical methods, such as can be employed in the case of copper, zinc, and any other ores that are soluble in acids. Also, as cassiterite unites with silica when they are heated together, one cannot do a fusion on a low grade material. It must be concentrated first. In certain cases a chemical assay may be required on raw material (see Chapter IV), but for the purpose of identifying cassiterite in lode stuff, or alluvial, a preliminary concentration should be made first.

1. In the case of lode stuff, or suspected shode stones, the material should be crushed to pass a 30-mesh sieve and then vanned (see Chapter IV).

2. In the case of alluvial, where there may be very little cassiterite in a large body of earth, it is necessary to pan down a *measured* quantity of the raw material, which should in no case be less than 30 lb. or 40 lb. of dirt.

In both cases the concentrate may be chiefly cassiterite, *or* a mixture of cassiterite and other heavy minerals, *or* there may be a concentrate which consists almost entirely of substances which are not cassiterite. Usually one can see at this stage whether cassiterite is present, but it is not safe to trust to appearances. The concentrates must be assayed to ascertain how much actual tin they contain.

[If it is simply a question of *identification* they can be tested with cyanide before the blow-pipe, but one cannot get quantitative results with the blow-pipe.]

Zinc Dust Test. When clean pieces of what is suspected to be cassiterite can be picked out as in panning alluvial, there is an easy way of distinguishing them from any other heavy minerals that may accompany them.

Place the concentrate in a saucer, sprinkle lightly over it some zinc dust, and then add some dilute sulphuric acid. The hydrogen liberated from the acid effects a surface reduction on the pieces which are cassiterite, so that they become covered with a thin greyish film of metallic tin. This film becomes brighter on being gently rubbed on any kind of fabric. All pieces that show this metallic coating should be picked out and weighed. Where the concentrate is mainly cassiterite, the dark pieces represent the impurities.

The Burette Test. As the specific gravity of cassiterite is between 6·8 and 7, it follows that 70 grm. of the clean

mineral will take up about the same space as 10 c.c. of water, and that if it displaces more water than this, there must be some other substance present which has a lower specific gravity. Any other substance of the same gravity as cassiterite would, of course, behave in the same way, so that *the test must not be relied on to indicate the purity of a tin concentrate when its composition is unknown.*

But in the case of concentrates, where the general composition is known, this test is very useful when it is desired to learn whether concentrates are clean enough to send away. Comparisons have shown that results can be obtained which agree within half per cent of the cyanide or chemical assay.

The test is carried out as follows ; place 126 grm. of the sample in a 50 c.c. burette which already contains a given quantity (say, 20 c.c.) of water, and note how much the water rises. It is clear that the purer the ore the less the rise, while if the ore is a mixture containing cassiterite and a substance of lower specific gravity, the rise will be greater. For instance, if after adding the 126 grm. of concentrate the rise is 18·7 c.c., this indicates that the concentrate contains 70·45 per cent of tin ; on the other hand, if the water displaced were much greater, for instance, 25 c.c., the concentrate is clearly poorer in tin, and according to the table would contain only 16·98 per cent.

In the table given on page 5, the first column, A, refers to the rise of water in cubic centimetres ; the second column, B, gives the specific gravity corresponding to such rise ; and the third column, C, shows the percentage of tin corresponding to this specific gravity.

Stannite. The only other ore of tin which has been worked in quantity is stannite. It is a variable mixture of tin, copper, iron, and sulphur ; it is known as " bell-metal ore " and as " tin pyrites." Its colour may be black, steel-grey, or bronze. It usually has some metallic lustre. It is decomposed by nitric acid, the copper goes into solution, and the tin is converted into metastannic acid, which appears as a white mud at the bottom of the bluish-green solution. The white mud tested before the blow-pipe with cyanide will yield a bead of metallic tin.

SPECIFIC GRAVITY OF TIN CONCENTRATES BY MEANS OF THE BURETTE

A	B	C	A	B	C	A	B	C
18·0	*7·000*	78·70	21·4	*5·888*	43·67	24·8	*5·080*	18·26
18·1	*6·961*	77·47	21·5	*5·860*	42·81	24·9	*5·060*	17·62
18·2	*6·923*	76·26	21·6	*5·833*	41·96	25·0	*5·040*	16·98
18·3	*6·885*	75·08	21·7	*5·806*	41·11	25·1	*5·020*	16·34
18·4	*6·848*	73·91	21·8	*5·779*	40·26	25·2	*5·000*	15·71
18·5	*6·811*	72·75	21·9	*5·753*	39·44	25·3	*4·980*	15·08
18·6	*6·774*	71·59	22·0	*5·727*	38·63	25·4	*4·960*	14·46
18·7	*6·738*	70·45	22·1	*5·701*	39·81	25·5	*4·940*	13·85
18·8	*6·702*	69·32	22·2	*5·675*	36·99	25·6	*4·921*	13·25
18·9	*6·666*	68·19	22·3	*5·650*	36·20	25·7	*4·902*	12·65
19·0	*6·631*	67·08	22·4	*5·625*	35·41	25·8	*4·883*	12·05
19·1	*6·596*	65·98	22·5	*5·600*	34·63	25·9	*4·864*	11·46
19·2	*6·562*	64·91	22·6	*5·575*	33·84	26·0	*4·846*	10·88
19·3	*6·528*	63·84	22·7	*5·550*	33·05	26·1	*4·827*	10·30
19·4	*6·494*	62·77	22·8	*5·526*	32·30	26·2	*4·809*	9·73
19·5	*6·461*	61·73	22·9	*5·502*	31·54	26·3	*4·790*	9·16
19·6	*6·428*	60·71	23·0	*5·478*	30·79	26·4	*4·772*	8·60
19·7	*6·396*	59·69	23·1	*5·454*	30·03	26·5	*4·755*	8·03
19·8	*6·364*	58·68	23·2	*5·430*	29·28	26·6	*4·738*	7·47
19·9	*6·332*	57·67	23·3	*5·407*	28·55	26·7	*4·719*	6·90
20·0	*6·300*	56·66	23·4	*5·384*	27·83	26·8	*4·701*	6·34
20·1	*6·269*	55·69	23·5	*5·361*	27·11	26·9	*4·684*	5·79
20·2	*6·238*	54·71	23·6	*5·338*	26·41	27·0	*4·667*	5·25
20·3	*6·207*	53·74	23·7	*5·316*	25·72	27·1	*4·649*	4·70
20·4	*6·176*	52·76	23·8	*5·294*	25·03	27·2	*4·632*	4·16
20·5	*6·146*	51·81	23·9	*5·272*	24·34	27·3	*4·615*	3·62
20·6	*6·116*	50·87	24·0	*5·250*	23·65	27·4	*4·598*	3·08
20·7	*6·086*	49·93	24·1	*5·228*	22·96	27·5	*4·581*	2·55
20·8	*6·057*	49·01	24·2	*5·207*	22·78	27·6	*4·565*	2·04
20·9	*6·028*	48·10	24·3	*5·185*	21·60	27·7	*4·548*	1·52
21·0	*6·000*	47·21	24·4	*5·164*	20·93	27·8	*4·532*	1·01
21·1	*5·971*	46·32	24·5	*5·142*	20·25	27·9	*4·516*	0·50
21·2	*5·943*	45·43	24·6	*5·121*	19·58	28·0	*4·500*	0·00
21·3	*5·915*	44·54	24·7	*5·101*	18·92			

The Occurrence of Cassiterite in Nature.

Cassiterite is found as a *primary* deposit in lodes, stock works, and impregnations in granite and contiguous rocks. When these disintegrate they give rise to *secondary* deposits of detrital and alluvial tin.

The general methods of prospecting and the search for primary deposits are described in Chapter II, while the testing of secondary deposits is described in Chapter VII.

Lodes. Tin lodes are found in granite or in the rocks overlying granite. What we call a lode was originally

a crack, or fissure, in the country rock, which in the course of a long period of time became filled in by a different material. It is now universally agreed that the lode material did not arrive in the lodes in a molten condition, as was formerly supposed, but was deposited from solution

Fig. 1. Portion of a Big Dam Built to Conserve Water
The water is then carried some 17 miles by pipe-line to the areas being worked
(*Tingha Hydraulic Tin Mines*)

or from vapour or from both. These vapours, or solutions, were derived from the granite while it was cooling, but not necessarily from that portion of the granite which is near the lode. They may have come from much greater depths. Elements such a fluorine, boron, phosphorus, etc., compounds of which are common in tin lodes, may have acted as "carriers." The minerals found in a lode may not all have arrived at one time. In some cases, there is definite reason for believing that one mineral arrived before another, or that the lode has received additions of the same mineral at different periods. So far as we know, tin lodes are not being formed to-day, at least at such depths of which we have any experience. Lodes vary in width from a few inches up to several feet.

They run through the country rock like a wall, possibly vertically but more often inclined. When they lean at an angle, the upper side is called the "hanging wall" and the lower side the "foot wall." Occasionally lodes dip sideways to such an extent that they become nearly horizontal, but the greater number approximate to the vertical.

Lodes, or lode channels, may run in more or less the same direction for several miles. In some districts they are fairly uniform in width, in others they widen and narrow again at frequent intervals. Most tin lodes continue to exist at the greatest depth to which they have been sunk on. The same lode may change its mineral contents at different depths, yielding copper in the upper levels and tin below.

The lode body, or material of which tin lodes consist, is variable. It generally consists principally of quartz with accessory non-metallic minerals, such as fluorspar, tourmaline, chlorite, apatite, topaz, etc. Cassiterite may be found as the only metallic mineral in a lode, or it may be accompanied by oxides of iron, iron pyrites, copper pyrites, arsenical pyrites, wolfram, and in a few localities by bismuth, antimony, lead, and silver.

In a tin lode the cassiterite is distributed in a variety of different ways: it may be chiefly on the foot wall, or on the hanging wall, or in a pay streak in the centre; it may be in more or less isolated crystals, bands, or pockets, sometimes a considerable mass of solid cassiterite is found.

Lodes which contain rich ore in some parts may be very poor or quite barren in others. In certain districts it has been found that the general average of the tin contents of the lodes is more uniform and higher than in other districts.

In the West of England, the general average of the ore (taken from a number of mines over several years) shows that the lode stuff sent to the mill contained between 1 and 2 per cent of recoverable cassiterite. It is, of course, often the case that large "shutes," or bodies of ores, amounting to hundreds or thousands of tons are found which give a considerably higher yield, but they will be counterbalanced by poorer ore in other parts of the mine,

so that it is rare in Cornwall for the general average of the ore from any mine to exceed 2 per cent, though it has been exceeded in past times, possibly because in old days the poorer portions of lodes were left standing. Donald MacAlister, writing of the tin lodes of the Falmouth and Camborne district (*Geological Memoir*, 1906) says : " The profitable parts of the lodes (containing anything over 1 per cent of tin) alternate with poor and barren parts. That the ores do not occur uniformly disseminated throughout the lodes is a point that cannot be too strongly emphasized." This applies with equal truth to tin deposits everywhere. The same lack of uniformity in the distribution of cassiterite in tin lodes occurs abroad ; in Bolivia, South Africa, Portugal, Spain, Tasmania, and, in fact, in all tin formations whether they are lodes, lenses, pipes, floors, or impregnations. Even where very large masses of granite are stanniferous, the values are seldom regularly distributed.

The shape, or contour, of the enriched portions of lodes has given rise to descriptive names. When the mineralized body is an elongated mass of some depth, but not extending far along the lode, it is termed a pipe. Where the mineralized body extends laterally, but not vertically, it is called a " course " of ore. A mass or series of bunches, which extends both laterally and vertically, is termed a " shute " of ore. A vertical shute is termed a " pipe." Besides these terms, other names have been given to irregularly shaped enrichments. A flat impregnation is known as a " floor," and a particularly rich pocket or bunch, penetrating the country rock laterally, as a " carbona." These irregular enrichments may either form part of the lode or be offshoots from it. Cassiterite is also sometimes found impregnating the country rock alongside the lode, or in a soft clayey formation, " fluccan," between the lode and the country rock.

A favourable situation for irregular enrichments is at or near the junction of the granite, with the sedimentary rock overlying it, but it is by no means a certainty that there will be any enrichments at such junctions.

Stockworks. A stanniferous " stockwork " is a formation where cassiterite is disseminated in granite, or in a rock overlying granite in a series of small veins, or

stringers like minute lodes. These small veins may be, collectively, several fathoms in width, and may, like a lode, run and carry mineral for a long distance. The mineral may be on the faces of the joints of the rock, or in apparently isolated pockets of crystals in the mass of the rock. In some cases a very large mass of rock has been found sufficiently enriched to make it worth while quarrying and stamping as a whole. Instances occur in Spain, Tasmania, the West of England, and elsewhere. Stockworks are sometimes found at depth as well as near the surface. Those which have been worked in Cornwall, as open-cast quarries, have not been carried below 200 ft. Some of them have been worked profitably even where the recovery did not exceed 3 lb. to 4 lb. of black tin to the ton, where water-power was available.

Impregnations. In addition to tin-bearing lodes and stockworks, there are enormous masses of very low-grade stanniferous granite in several tin-bearing countries. In such granite the cassiterite is distributed, generally very sparsely, in spots, stringers, or isolated crystals.

Generally speaking, this stanniferous granite is far too poor to work for tin, as it often contains only a pound or two per ton. Where conditions have been favourable to its disintegration on a large scale, it has yielded vast quantities of alluvial tin.

In a few cases stanniferous granite has been found rich enough to mine, but the places that are payable are a very small proportion of the masses of very low-grade rock. In such stanniferous granite, it is not at all unusual to find small local enrichments of a soft altered granite, yielding perhaps 5 or up to 10 per cent of cassiterite, but as a rule such enrichments are too small and scattered to be of any practical use.

CHAPTER II

PROSPECTING FOR TIN

The duties and qualifications of a prospector—Warning that many deposits are unpayable, and that all observations must be made with the utmost care and accuracy—How to make a general search for cassiterite—Panning and verification of concentrates—Whether to search for lodes or alluvial—Searching for lodes in a virgin country —Shode stones—Warning against small samples—Opening up a lode by costean pits—Recording the length of the enriched and barren portions of a lode at surface—Quartering and crushing—Warning against sinking without advice—Examination of "prospects" by engineers—Importance of size and continuity of deposit—Searching for lodes in an old mining area

Foreword.

THE work of a prospector should only be undertaken by those who possess good health, and prefer an outdoor life, and are prepared to work under conditions which may entail some hardships and solitude. On the other hand, this class of work, if properly carried out, has a charm of its own, and as experience is gained a man has the pleasure of feeling confidence in his work.

There are several qualifications that a good prospector must possess; the most important are *accuracy and reliability, next comes experience.* Any lack of care on his part will probably lead to his getting higher "values" than actually exist, and when an engineer examines the place, quite different and disappointing results will be obtained. Again, if carelessly obtained figures are *not* checked by an engineer, the result may be that after a considerable expenditure in development and machinery, it is found that the recoverable mineral falls far short of what was expected.

Tin deposits vary in value in all tin-bearing districts, many are too poor to work. The duty of the prospector is to find and make accurate observations on those which will pay.

The prospector's work is that of the pioneer, but it merges in that of the mining engineer who follows him. In order that a prospector may gauge the amount of time he ought to spend in testing any particular area, he must

acquire a general knowledge of how lode and alluvial properties are worked, and the circumstances that make profitable working possible in each case.

Comparatively few rich deposits now remain, and most of the tin raised comes from low-grade deposits, carefully chosen because they are adapted for *cheap working on a large scale.*

There are a few pieces of general advice which can be given to those who desire to undertake prospecting for tin—

1. Make yourself thoroughly acquainted with the use of the vanning shovel and the pan, and with the identification and assay of tin ore and concentrates.

2. Before attempting to work alone go with an experienced prospector and study his methods.

3. Be careful to learn and comply with the mining regulations of the country you are going to work in.

4. Remember that all your observations will have to be checked by an engineer, and take the utmost care to avoid any possible errors in recording depths, values, measurements, etc.

5. For one payable deposit that you find you may have to examine several others which, for one reason or another, would not be payable.

6. Before starting work in the field see that you have a proper outfit, camping gear, food, and medical stores to keep yourself healthy and efficient, and the necessary appliances to test lodes and alluvial in such a way that your figures can be confirmed by other observers.

7. Study any books, maps, geological reports, etc., that can be obtained relating to the district in which you are going to work.

Note. Proper legal authority must be obtained from the Mining Department, or from the private owner of land, as the case may be. This is granted in the form of a permit, or licence, which either defines exactly the area in which search may be made, or gives a general permission to search over public lands. The licence confers a title to discoveries under certain defined conditions.

These are usually quite simple, and include provision that the discoverer must notify his discovery and indicate

the area by beacons, trenches, or notices. A prospecting licence does not always confer the right to remove minerals (other than samples), but it gives a preferential right to obtain a mining lease under given conditions, which usually require some actual exploration to be carried out within a given period.

We come now to the methods employed in making a general search for tin. It occurs as a *primary* deposit in lodes, stockworks, and in stanniferous granite, and as a *secondary* deposit in detrital and alluvial. Both of these are formed from the primary deposits. Detrital deposits are those where the primary deposits have been decomposed, but have not been carried far or sorted by the action of water. They may lie on the top of the primary deposit. Alluvial deposits are those where the material produced from the decomposition of the primary deposit has been carried down, spread out, and sorted by water. In some countries secondary deposits have been formed from lodes, in others the detrital and alluvial tin that is found has *not* been derived from lodes, but from stanniferous granite, and *no workable lodes are to be found.* For this reason in searching for tin it is better to look for secondary deposits in the *first case*, as workable deposits of these may be found whether lodes are there or not.

The preliminary search for cassiterite should be made either in a stream bed, or by sinking a series of pits along the bank of a stream or river. They should be sunk (as far as possible) so that one can reach " bottom " without finishing the pit in water. The object of these pits is to ascertain the presence or absence of cassiterite, and to get an idea of its quantity.

It is best to do this in the dry season when the water level is low. The " bottom " may be rock or clay, above this there is generally a " wash," that is, a mixture of pebbles and sand. This is generally where most of the mineral will be found.

If one is seeking to ascertain the *presence or absence* of cassiterite and *not* its quantity, the dirt next to the bottom should be panned. But if we desire to learn the *quantity* of cassiterite present, it is essential to get a *proper proportion of the poorer overburden as well.*

It is better to make it an invariable rule to take

measured cuts (say, 3 in. by 4 in.) from *top to bottom*, calculate what fraction of a cubic yard the dirt occupies, and pan it down. The concentrate is weighed on a small portable balance with gramme weights, or if the concentrates from several pannings are bulked together, ounce weights can be used. Accurate measurements should always be taken of alluvial for pannings. In shallow ground it is simple to take carefully measured cuts down the sides of a pit and to collect the dirt from these cuts in a rubber ground sheet spread on the floor of the pit. The quantity should be checked by ramming it into a box of known capacity. It is a mistake to be content with small samples ; if the pit is a shallow one, so that the measured cuts down one side only yield two or three pans of dirt, take cuts down other sides as well, so that no less than a cubic foot is panned. The length and size of the cuts should be entered in the notebook, the ground sheet gathered together and taken to water. Panning is carried out as follows. Place enough of the dirt to be washed to fill the pan about two-thirds full, sink the pan under water in a stream or pool, and rub up the material with the hands and pour off the muddy water ; repeat this till the water is clear. The stones are picked out and reserved for examination. We have now in the pan clean sand, small gravel, and any heavy concentrate that may have been present in the dirt. The pan is raised above water and shaken sideways to cause the heavier matters to arrange themselves at the bottom of the pan, with the lighter materials over them. The shaking movement is continued, and the pan is carefully and frequently tilted so as to cause the lighter materials to wash over the edge, while keeping the heavy concentrate in the pan. It saves time to transfer the partly washed concentrate from several pans (which are all part of the same sample) to another pan until all the dirt has been washed, and then clean the united concentrates. It is at the end of the operation, when most of the light sand has been washed away, that special care is required to prevent any loss of mineral. If the dirt is free from clay, the washing of a few pans of dirt does not take long, but if there is clay in the dirt, it must be all broken up and well puddled, and this takes time. The concentrates are dried and

weighed. They may be tested with zinc dust and acid, as described in Chapter I. If any grains are seen which do not show the metallic coating, they should be picked out and weighed, for they are not cassiterite. If they are crushed and yield a chocolate coloured powder they may be wolfram, while tantalite gives a dull red or black powder. Magnetite is removed by a good hand magnet.

Fig. 2. Mode of Transport which has to be Employed in places

(*Tavoy Tin Dredging Corporation*)

The grains of cassiterite may have small particles of stony matter attached to them, so it is well to give them a light crushing and wash them on the vanning shovel (see Chapter IV). If all the mineral throws up *together*, and the zinc test is positive, it is probably all cassiterite, but anything that washes away or will not pitch up is certainly not cassiterite. *To make certain it is necessary to do a fusion with cyanide, or with anthracite, and obtain the tin as a button of metal* (see Chapter IV).

The stones that were picked out during panning should be crushed to a 30-mesh powder, panned down, and finished on the vanning shovel. If any tin is found, some of them are "shode stones," which have come from a primary formation possibly not far away.

After the prospector has established the existence of cassiterite by the preliminary work described above, he must decide whether to give his attention to a search for lodes or for alluvial. If he is working in a country where both are known to exist, it might be best to search for lodes during the wet season ; on the other hand, in a country where there is no great probability of finding lodes, attention should be given to searching for a *large area* carrying alluvial tin, if possible commanded by water under a natural head. Small, shallow, or very poor areas are of very little use. The preliminary examination of the ground may have shown that some of the streams, or rivers, terminate in large alluvial flats. These are the places where large deposits may be found. Plant is required for the testing of deep ground. An individual prospector can locate ground for subsequent boring, but there is no boring plant that can be used single-handed except light augers, which are convenient for taking samples at a depth of 8 ft. or 9 ft. Boring plant requires four white men and a horse, or one white man and ten "boys." The use of boring plant is described in Chapter VII, which is devoted to the testing of alluvial ground. The reader's attention is particularly directed to the special care required to get *accurate* results from pits, and the precautions that must be taken, which are given in that chapter.

Searching for Lodes in Virgin Country.

In countries where no mining has been done, outcrops carrying payable ore may be found, or if the outcrops are concealed by cultivation or thick bush, "shode stones," that is, pieces of mineralized lode matter naturally shed from the lode, may be found lying on the surface, or may be found on washing surface earth.

On flat ground these shode stones are generally not far from the lode itself. After rains, when the surface stones are washed clean, it is often possible to trace the course of the lode from the shode stones lying on the surface. If no shode stones can be seen, the sides of hills and banks of streams, where bare rock is exposed, are the places to examine first. Lodes are seldom easy to locate on flat ground on account of their being obscured by earth

and vegetation: besides this, many lodes are "blind lodes," that is, they are a few feet underground along part of their course, and so would not be found without trenching except at the places where they chance to come to surface, and these places may not be found except after a long search. On high ground the search for lodes can be carried out during the wet season, when it would be impossible to make an effective examination of alluvial flats or stream beds.

Shode stones are sometimes very easy to recognize. If they carry a large proportion of tin their weight alone will be noticeable. If they are a white quartz, with large black or brown crystals of cassiterite showing, they catch the eye at once. But a brown cassiterite in a brown stone is not so easily seen. They may be small or large, sometimes they are of many pounds weight and very rich, or they may contain only a few pounds of tin to the ton and yet give a clue to the position of a payable lode. Solid crystals, or lumps of cassiterite, are not necessarily shed from a lode, they may have come from other formations. But when one finds a number of stones carrying tin in quartz, or the other lode materials mentioned in Chapter I, it is probable that a lode is not far away. If they are found in a stream bed, the lode will probably be either close to or some little distance upstream, or on the higher ground on one side. A steep bank by the side of a stream or river is an excellent place to search for lodes, because the bare rock is often exposed and the lode stands out so that it is in contrast to the country rock. A lode may be nearly black owing to the presence or tourmaline, or brown or reddish owing to iron compounds. One must not expect that the cassiterite crystals will always be large enough to be detected at once by the naked eye. In a brown rock it is nearly impossible to be sure of detecting brown cassiterite even with a lens. In a tin district every lode should be examined by crushing and vanning, for the exposure first noticed may not contain visible cassiterite, but may still lead the way to a payable deposit. It is no use spending time on very narrow lodes, or stringers, for even if they are rich they would not be workable unless there is a series of them that can be worked as a whole. But when a lode is seen which is

a workable width, say, over 30 in. wide, it is worth examination even if it only carries a little tin at the first point tested. The values that would pay to work depend on local conditions: in a temperate climate 30 lb. to 40 lb. of cassiterite to the ton would pay; in the tropics either a higher value, or a greater width, might be needed to give a good margin of profit. But before any idea can be formed as to the usefulness of an exposure, it is necessary to test it as regards *continuity on surface.* This is done by uncovering the exposure so that one can see the *direction* of the lode, and then digging a series of "costean" or trial pits at intervals, so as to expose the lode and sample it systematically. These costean pits should be made in the first instance 10 ft. apart. The lode may not run quite in a straight line, so that to pick up the lode some of the pits (which are dug at right angles to its supposed course) may have to be longer than others. As regards their depth, they must be taken deep enough to get on to the unbroken lode, and to clear it from surface rubbish. The object of these costeans is to enable the observer to measure the *width* at each point, and to take a sample and see what tin there is in the lode at that point.

In taking samples the essential point to observe is that they must be taken *right across the lode from wall to wall.* There is often a pay streak in the centre or at one side, and if more of this is included in the sample than the remainder, which may be poorer, a false result will be obtained and the observer will be discredited. It is impossible to be too careful on this point. Careless sampling has led to mistakes on innumerable occasions, but if due care is taken accurate results can be obtained. Before the samples are cut the surface of the exposure must be even and flat, so that a cut can be made right across, taking quite *impartially from wall to wall, hard and soft, rich or poor, in exactly the same proportion* as they exist in the lode. The quantity taken from a lode 3 ft. wide should not be *less* than 20 lb. This quantity should be crushed down in a mortar, or on a bucking board, to the size of maize grains. It is then placed on a rubber sampling sheet and *well mixed*, and divided into four quarters. Two opposite quarters are taken and crushed

again to about the size of wheat, and again mixed and quartered. As before, it is crushed and quartered again, and the two opposite quarters are taken. The reduced quantity is now crushed until it *all* passes a 30-mesh sieve. It is then vanned and the vannings are saved in order to get a sufficient quantity to ascertain the actual percentage of tin (see Chapter IV).

The costeaning should be carried on as far as the lode can be traced, unless the results that are being obtained show that it is too poor to be of any practical use. If, for example, the results show that some of the costeans (at 10 ft. intervals) carry under 20 lb. of black tin, and the average of those that *do* carry tin is not above 20 lb. to 25 lb., and that they are separated by other exposures which are unmineralized, it is very doubtful if the lode would be payable. On the other hand, if consistently good results are obtained averaging, say, 30 lb. to 40 lb., and the lode maintains its width, it is advisable to enlarge the costean pits and work out a few tons of ore from each place. The reason for doing this is that many lodes contain small pockets and patches which are exceptionally rich, which taken alone would give a false idea of their value. The ore should be broken to the size of road metal in the first case and quartered, crushing and quartering as required until ready for vanning.

If the ore is a coarse crystal tin ore and cheap labour is available, it can be bucked down and jigged or panned. In this way a bulk test can be made, all the coarse tin can be recovered, and the tails can be tested to see what further amount could be got from them. A small sluice box, 12 in. wide and 8 ft. long, is convenient to wash lode stuff that has been bucked down, and the bucking can be done on any large pieces of hard rock that are available.

If the lode is a very wide one, and the results from a series of costean pits show that the mineralization is uniform, a considerably lower percentage of tin would be payable. (See under "Stockworks.") There are also cases where a short length of mineralized lode would pay, such as where the mineral is concentrated in pipes.

But both of these formations are rare compared with the ordinary type of tin lode. In the ordinary type of

tin lode it is essential to find a shute, or course of ore, which is mineralized over a *considerable horizontal length* (showing that it is probable that there is *continuity* before it is worth thinking of exploring it in depth). An example is given farther on to show why this is so. If, therefore, the prospector finds that he is getting poor or very variable results from his costeans on a particular lode, he should not stay there too long, for there may be others near by which he will find where the mineralized portions are larger or richer.

Prospectors are often inclined to stop their surface work directly they find a single enrichment and to want to sink on it.

This is a mistake, for if there is one enrichment there are probably others, and if they are located they add to the value of the prospect.

Before attempting to do any sinking a prospector will always be wise to get advice, particularly if the lode he has found does not show well-defined walls. At surface the walls of lodes are not always well defined, and if the formation is not a true fissure lode he may be wasting his time. There are many places where attractive looking patches and pockets of cassiterite are found in granite, in pegmatite dykes and in quartz blows, which are not parts of a definite lode, and have no continuity or practical value. It is for this reason that it is advisable to work out a quantity of ore from all those costean pits which show payable values.

If these piles of ore after quartering and vanning show the presence of, say, 1 or 2 per cent of cassiterite, and the floor of the underhand stopes is still showing minerals, and the lode is of workable width, the " prospect " is a favourable one. But until underground exploration has been carried out it will not be possible to say if the ore bodies are large enough to be worth mining.

If the prospector is working for a company, he will report his results and receive instructions ; if he is acting for himself he should arrange with an experienced engineer to advise him.

It is a mistake to call in an engineer until a prospect has been sufficiently opened up for him to examine it thoroughly, and is not satisfactory to either party. After

it has been opened up, as above described, the engineer will be able to say whether it is deserving of fuller exploration, and will probably be able to place the discoverer in touch with people who could do so.

Examination of "Prospects" by Engineers. Prospectors sometimes expect that an engineer will be able to say after examining a prospect that it is likely to turn out a payable mine. No experienced engineer can hold out such hopes or would make such a statement. But he can say whether it deserves exploration in depth or otherwise, and what is the best course to pursue. The prospector should not be discouraged if he is advised to do further work, for this is an excellent proof that the engineer considers the prospect has merits, and is worthy of closer investigation.

An experienced engineer, in examining a "prospect" or surface discovery of tin in lode formation, looks at once to the practical and commercial side of it ; that is, whether the discovery is likely to prove *large* enough to justify exploration in the first case, and the expenditure of money on plant at a later date. Therefore he attaches particular importance to the *horizontal length* of the enrichments, the width of the lode, and whether it has well-defined walls ; in other words, whether it shows evidence of *size and continuity.* Very short courses of ore are to him far less satisfactory than those which are long horizontally. An example may serve to illustrate this. Take the case of an enriched portion of lode, where it is found that the horizontal length at surface is 100 ft. To test this in depth a winze 100 ft. deep will be needed, with the necessary cross-cuts and drives. These might cost, say, £1,200, and result in the opening up of possibly 1,200 tons of ore. In this case we have a development charge of something like 20s. a ton before we can break any ore. Now compare this with a shute (or enrichment) which is not 100 ft., but 300 ft. in horizontal length. Here, just the same initial expenditure would open up a body probably three times as large. It is true there will be a little more driving to do, but the development charge is spread over a much larger tonnage, and may work out to 6s. or 7s. a ton, instead of nearly 20s.

In addition to this, if the enrichments at surface are

large, it is more probable that those we cannot see may be larger also than would be the case if all those at surface were small. This example is given to bring home to the reader that while there are a great number of places where some tin can be found in outcrops, the prospector has to exercise discrimination (which can only be learned by experience). But the reader will at once appreciate that it is better to examine several outcrops until he has found one which will be regarded as a " legitimate mining risk " by an engineer of wide experience, than waste his employer's or his own money in " taking chances." There are inherent risks in lode exploration which not even the most experienced can always foresee ; this makes it all the more important to carry out the initial surface exploration as thoroughly and carefully as can possibly be done.

Searching for Lodes in an Old Mining Area.

In a country where much mining has been done, it is not likely that outcrops will be found where payable ore is showing at surface. The outcrops that once existed will now be indicated by excavations. From the character of these one can form some idea of what was done previously. If the old workings are only a series of isolated trial pits, they show that a search was made, but that nothing was found that was considered payable at that time.

On the other hand, if the old workings are continuous trenches and the surface is much tumbled, it shows that the former workers found enough mineral to cause them to open the lode in length along the back, and to work it away at any rate to a depth of some feet. Where they found the lode payable they usually followed the pay shutes down as far as they were able.

These surface workings were often followed up by bringing in an adit, and in the majority of cases where adits were driven it will be found that all the ore above adit has been taken out unless it was very poor or very hard. Deeper workings are indicated by shafts, dumps, the foundations of buildings, wheel-pits, or water courses. Where mining has been carried out it is natural to expect that any large pieces of ore lying on the surface will be poor,

as the piles would have been picked over probably more than once. The failure to find good ore is not a proof that good ore was not raised, and further information may be gained by panning the "fines," for if they have not been washed already they will give a better idea of the ore formerly raised than the larger pieces.

CHAPTER III

The sampling of mines, dumps, tailings, beach sands, etc.—Consideration of the best method of arriving at the value of abandoned workings which are partly under water, from records, from the examination of dumps, tailings, mill capacity, etc.

Direct Sampling of Mines.

It has already been pointed out that profitable parts of the lodes are disposed in what are known as shutes, courses, and pipes, when they are of considerable size; smaller enrichments are termed bunches, or pockets. The first thing to realize about tin mines is that, owing to the fact that the ores do not occur uniformly disseminated throughout the lodes, we must not attach too much importance to " samples " until we know what bulk they represent. Let us imagine a drive which has been going through some fathoms of poor lode stuff, and has arrived at a face which, on being carefully sampled, quartered, and vanned, shows 100 lb. of black tin to the ton.

This would be an encouraging figure, but until the drive is continued we cannot form any idea of the *size* of the enrichment.

In some districts it would probably turn out to be a large one, in others it might be a very small one, in any case its size can only be proved by actual exploration. Let us suppose that the drive is continued, and that similar results are found as samples are examined every few feet for a distance of several fathoms.

It is obvious now that we have an enrichment of some length; it may have already been seen in the levels above, and on driving the levels below it may be cut again, but until it has been *blocked out* we do not know its size. These enrichments are not equally mineralized throughout, they vary from a few pounds of black tin to the ton up to very rich ore, but taking a general average they contain from 1 up to 2 per cent of black tin.

The art of mining is to find one's way from one enrichment to another as quickly and cheaply as possible, and to work out the enriched portions without breaking any more poor or barren lode stuff than can be helped.

It must be freely admitted that we have no means at present by which we can sample a lode mine as easily as we can an alluvial flat. In an alluvial flat the values are *comparatively* uniform over a considerable area ; they are at no great depth and they can be reached and sampled by boring gear. We cannot test the width of the lodes, or the values in them, in a tin mine as quickly or as thoroughly or as cheaply. Ordinary sampling in a lode mine is confined to chipping the surface of the faces, roofs, or floors, so that we are only sampling the surface skin. With a hand-drill, holes can be put down 3 ft. or 4 ft., and we can van the pulp from the holes. With an air-drill deeper holes can be made, and with a diamond drill tests can be made at a distance of many fathoms. If tin lodes were more uniform in their contents there is no doubt that diamond drilling would be more frequently employed, and it is meeting with considerable success in Cornwall at the present time.

In sampling tin lodes care must be taken to cut samples right across the lode, so that if there happens to be a " pay streak " the correct proportion of tin is taken to the poorer material. The walls of the lode should also be examined, as they sometimes carry mineral.

Sometimes it is desired to examine the upper portion of an old tin mine, of which the principal workings are under water. Here, again, one should remember the old saying that " the mill is the best sampler," and if it is possible to get the milling returns, they should be compared with any results on ore at present capable of being examined.

If no milling returns can be traced, it is necessary to sample all such parts of the lodes that can be reached. We cannot expect to find *representative* ore in sight in an abandoned working, as it has been removed by previous working, unless it has been intentionally left to impress possible investors. Therefore, before taking samples, the ends should be driven, whether they show ore in sight or not ; and the loose dirt should be dug up under old stopes so that the unbroken ground can be sampled. It is useless to sample over a lot of abandoned stopes only, for the payable portion of the lodes has been taken out, and other shutes and bunches of ore that may exist are too deeply

buried to be reached by sampling. But in the floors of the levels the position is very similar to that of a virgin outcrop ; that is, the best portions remain, and if the level of the water permits we may be able to work out some tons between levels, and so get a much better idea of its value than can be gained from small samples. A great many tin mines were abandoned by the " old men " when they reached water, or when they got a little deeper and were not able to keep the water out by the means at their command. Mines were also worked and abandoned not because there was no tin, but for a variety of reasons, such as want of capital, variations of price of the metal, etc.

The fall of price which occurred in 1870–75, and again in 1895, caused the closing of many mines, because the price fell to £40–£50, whereas the cost of production was above this figure as far as lode tin mines were concerned. The price of metallic tin to-day is much higher and seems likely to remain around £300, so that there is a probability that some of these mines may be reopened with satisfactory results. Examination of the geological maps shows that there is a very large number of lodes which have only been worked to very shallow depths. In some of these abandoned mines nearly all the workings are under water, so that direct sampling is impossible.

Indirect Sampling of Mines.

" Indirect sampling," that is, a careful examination of any dumps or sand-piles that remain, taken in conjunction with such other evidence as can be collected, will assist in selecting those areas which may be considered " legitimate mining undertakings."

If an ore dump is very poor on the outside, or if the larger pieces of ore are very poor, this may be due to its having been " picked," but if the fines are very poor, the original ore was poor. The sand residues also afford some useful information. An assay of the sands does not in itself afford an indication of the original quality of the ore, for one may get a poor tailing sand from a rich ore.

For instance, if the tin was a rough-grained (large crystal) ore, and originally enclosed in a light gangue, the residual sand would be poor even if the ore had been rich.

Again, one may get a tailing sand fairly rich in tin from a poor ore, if it contained accessory minerals which made the extraction difficult.

The capacity of the mill formerly used and the time it ran can often be ascertained ; this will give a clue to the amount of ore that was stamped and if records of sales exist, which can often be traced through the mineral

Fig. 3. Sluicing Down a Paddock with the Monitors
(*Tingha Hydraulic Tin Mines*)

landlords or from the smelters who purchased the concentrates, a fair judgment may be formed of the value in pounds of black tin per ton that was recovered in the former working. In some cases, mine books still exist, and plans of underground workings are in the possession of individuals or at the Home Office. Unless all the various pieces of evidence that can be collected together in this way are found to confirm one another, the reopening of an abandoned mine must be regarded as speculative. But if satisfactory evidence can be collected as to the size of the ore bodies, and the general value of the ore previously milled, a good deal of uncertainty can be removed.

The Sampling of Dumps.

These may be examined for the reason mentioned above, or it may be discovered that the dump would pay to work as a proposition by itself.

Many dumps have been successfully worked, as they contained ore which was not good enough to put through mills of small capacity when richer material was available, and the price of tin was low, or they contained complex mixtures of copper, wolfram, arsenic, and tin, so that their treatment was not considered worth while at the time the ore was being raised. Some mines started as copper mines and the ore gradually became less coppery and more tinny. Years ago arsenic and wolfram were so low in value that their presence in a tin mine was a source of expense rather than an asset. Now all these conditions have changed, therefore judgment must be based on present-day factors.

Dumps exist to-day which will pay for treatment on correct lines, but it is very easy to lose money on a dump proposition unless every care is taken to look into all the circumstances before laying down any plant. The first thing is to ascertain the true contents of the dump, and what proportion of the theoretical values can be brought to a marketable condition.

The following suggestions will be of use in testing dumps—

1. Do not judge a dump from a few piles of stones picked off the outside : the interior may be very different.

2. Do not assume that the interior is loose : the lode stuff and country rock are sometimes cemented together owing to the oxidation of iron pyrites.

3. A skilled dump-picker can collect ore quickly from the outside of a dump where the ore is rain-washed and clean. In the interior the stones may be so stained that it is difficult to tell ore from waste rock.

In the first case *vanning assays* should be made on samples, taken at a large number of places all over the dump. These samples should be not less than 56 lb. each. After taking them the barren rock should be picked out and the weight recorded. The remainder should be quartered and vanned. If a dump of, say, 500,000 tons were being dealt with, at least 100 samples

should be taken. The vanning concentrates should be assayed for tin, copper, wolfram, and arsenic. If these assays indicate a good margin of profit the next step would be to examine the interior of the dump. Tram lines should be laid to it and cuts made into it, the waste rock should be trammed to one place and lode stuff and fines to another. After a few days' work it will be possible to measure the relative proportion of ore to waste rock.

If it is possible to hire the use of a neighbouring mill it should be done, if not a small battery should be set up and run with a portable engine. For the purposes of testing it would be sufficient to use buddles. The concentrates obtained from this simple plant can then be offered to a mine where the plant already exists for working up such concentrates. If the result is satisfactory a larger and more complete plant can be obtained.

The Sampling and Testing of Sand Dumps.

In the case of some tin mines, the sands were thrown into water courses and lost. In others the sand dumps remain. Sand dumps do not necessarily vary in richness according to the ore from which they were derived. Their quality will also depend on the completeness of the plant formerly used. Very few sand dumps contain free tin, but they all contain tin in locked grains often associated with copper, wolfram, and arsenic.

Just as in the case of dumps, sands should be examined by vanning tests in the first instance. Chemical assays are misleading unless preceded by vanning, as they give no indication of the recovery, which is the important point. The interior of sand dumps may be concreted together, in which case they would probably be unworkable. If vanning tests on material, taken from the outside, indicate a good margin of profit, a working trial should be made by running several hundred tons, taken from all round the dump, either direct through pulverizers on to shaking tables, or first over tables and then through pulverizers.

With some sands it pays to grind everything, with others a proportion of poor sand can be discarded before grinding. A slimes plant consisting of two or three round frames will be needed as well. Before setting up tables or grinding plant, some careful experimenting with the

vanning shovel, and sieving tests, will indicate the degree to which grinding must be carried to get the best results.

The Sampling of Beach Sands.

There is a varying quantity of cassiterite on several of the Cornish beaches, and on the shores of Tasmania and other stanniferous districts abroad. Some of these have been worked continuously for many years. The mineral may be derived from mine tailings, or in some cases from lodes running from the land under the sea. It is seldom that any large proportion of the tin is free, it occurs attached to particles of sand. A stanniferous beach varies in quality according to the season, tides, weather, wind, currents, etc. Under favourable conditions the barren yellow sand is less abundant, and the darker sand contains more tin. Besides this there are often surface concentrations. These may be local or widespread. They are found in the form of ripples or flat patches of varying extent and thickness, and may be on surface or covered by yellow sand. These concentrations may vary from tide to tide, and are most prevalent after rough weather. As a rule, it is customary to effect a concentration on the beach before grinding. The best place to look for payable sand is the strip of beach nearest to the cliff, but owing to the influence of winds and currents, enrichments may occur in unexpected places, and even those who have spent a lifetime in examining beaches, to decide which portions are to be carted up, do not rely on the appearance, but carry a vanning shovel and mark off the area which they are going to send carters to bring up.

At one well-known beach a strip some 50 yd. wide is nearly always being enriched for a distance of two miles in length, but other parts of the same beach which are under normal conditions poor, are sometimes covered by a very rich layer of tin sands, and it is necessary to make a daily inspection of the beach to find if any fresh enrichments have formed during the night. The transportation of the sand is generally effected by carts with wide wheels. It is necessary to maintain a stock of sand at the works, or at a suitable place above tide level, to keep the plant regularly at work.

The best way to test a beach would be to carry out a

trial over several weeks, so as to include periods of fine weather and rough weather. Several cart loads of sand should be concentrated each day just as they would be in practical working. The sand chosen for concentration should be selected by vanning tests, and the area seen to be enriched recorded daily. The concentrates should be assayed daily by vanning tests and by chemical assay. The chemical assay gives the *total* quantity of tin present, while the vanning assay will correspond more nearly with what can be actually extracted.

The bulked concentrates should then be taken to a plant where they can be ground and dressed up. The dressed tin should be assayed and sold, and the tailings assayed. In this way reliable information will be obtained as to the real extraction that is obtainable.

CHAPTER IV

The assay of tin ores, tailings, concentrates, etc.—Vanning and the verification of the concentrates obtained—Reasons why vanning is to be preferred to chemical assays for some purposes

THE commercial value of a tin ore does not depend on the percentage of tin only. It depends on (1) the amount of marketable cassiterite that can be recovered, and (2) the cost of treatment.

An ore which contains the cassiterite in large crystals, with a light gangue, can be dressed cheaply with little loss. An ore in which the cassiterite is in very fine particles will give a lower recovery, and cost more to extract. The presence of pyritic impurities will necessitate roasting, and if antimony, lead, bismuth, or scheelite is present, chemical treatment will be needed.

The object of any assay is to obtain information on which some action involving outlay is based, hence it is essential that the true meaning and limitation of assays should be realized. There is often a confusion between what an ore contains and what it is possible to extract; in other words, between its theoretical and its commercial value. This difference between what an ore contains and what one can get out applies, of course, to all ores of all metals. Some ores are so complex that they have no practical commercial value, even though they contain a considerable quantity of minerals that would be valuable if their separation could be effected cheaply.

Assuming that samples have been taken and quartered down properly, the next thing to decide is how they should be assayed. A chemical assay will tell us the total quantity of tin present, but gives no indication of the loss in dressing, so that for tin ore a mechanical assay is best in the first case, because it tells us what can be *extracted.*

Mechanical Assay of Tin Ore. The vanning assay is a method of separating any heavy substance from substances of lower specific gravity by the aid of water and motion. It is a form of panning, but it necessitates the use of much less mineral at a time than can be used in a

pan. For success in vanning three things are necessary: skill and patience on the part of the vanner; the water and appliances must be clean and free from any trace of grease; the ore must be crushed to a proper size. The blade of the vanning shovel is made of thin sheet iron, it weighs about 3 lb., is 14 in. or 15 in. long by 13 in. wide, and is " dished " nearly an inch deep in the centre. It has a socket to take the handle, which is about 3 ft. long. The surface of the vanning shovel must be kept quite smooth and clean. It is permissible to rub down sands on the shovel during tests with a hammer or smooth pebble, but stones must never be crushed on it, as the surface must be kept perfectly smooth and free from dents, scratches, and rust. It should be dried after use and kept in a dry place, or it will soon be pitted with rust and then accurate work is impossible.

The sample should first be reduced to a 30-mesh powder and well mixed before weighing out. The quantity of ore weighed out should be 20 grm., unless the operator prefers to use grain weights. The whole quantity should not be placed on the shovel at once, but sieved through 60-mesh and 90-mesh sieves, and the separate fractions vanned separately. The sands and muddy water are saved for retreatment. The operator stands before a shallow vessel filled with clear water (a large enamelled basin is most suitable) and, holding the shovel level, he places on it the ore to be vanned. He takes a little water on the shovel and well moistens the ore, taking care to see that none of it floats. If any particles are seen to float they are caused to sink by flicking fine drops of water on to them. More water is now added to the wet ore, and the shovel is given a circular motion so as to get the fine mud in suspension, and the muddy water is poured off into the vessel. This process is continued until the water on the shovel is clear. The ore is now brought by swirling with water into the centre of the shovel, and a separation of the sand and cassiterite is made by continuing the swirling motion with occasional sharp " cants " or jerks.

The effect of these " cants " is to cause the heavy particles of ore to travel towards the front end of the shovel, while the water causes the sands to travel back.

The mineral forms an edge, or tongue, towards the tip of the shovel. By the use of successive small quantities of water the sands are brought to the back of the shovel and the mineral to the tip, free from sand. The mineral is gently dried on the shovel and brushed off.

The other fractions are treated in the same way, the cleaned concentrates being added together and reserved. We have now in the water all the sands and the mud. The latter is stirred up, poured into another vessel and settled, as it will contain slime tin. The sands are got on to the shovel and rubbed down with a flat-headed hammer or a pebble, and vanned again. A little more concentrate is collected, dried, and saved. We have now collected all the coarse and fine tin, and the sands have been ground to a mud. This mud is placed on the shovel and washed with small successive quantities of water, in order to save the "slime tin." In vanning slimes one cannot pitch up the cassiterite as in the case of crop tin. The quantities of water used must be smaller and the motion more gentle. Here we depend on the fact that slime tin adheres to the surface of the shovel, while we wash off the layer of fine mud from the surface. It is impossible to effect a *perfect* separation; some of the slime tin is in a microscopic powder and is certain to be washed away, some is still attached to particles of gangue, however carefully we grind, but with care the cassiterite saved on the shovel represents *nearly* all that can be recovered in practical working on a large scale.

Hence, vanning tests, carefully carried out, give us a close idea of the commercial extraction that will be possible.

The concentrates that have been obtained are now added together, dried, and weighed. Multiplied by five (if 20 grm. has been taken) we get the percentage, and this multiplied by 22·4 gives us the number of pounds of *concentrate* per ton.

We come now to consider the composition of this vanning concentrate. It has been already mentioned that tin ores are seldom a mixture of pure cassiterite and gangue, and heavy impurities are often present.

In the absence of heavy impurities the vanning concentrate would be a clean marketable "black tin," and could

be assayed at once by the cyanide, or a chemical method, to learn its percentage of metallic tin.

On outcrops, and in the upper levels of mines, heavy mineral impurities may be absent or nearly so, but in most mines there is a varying amount of heavy mineral impurity, which must be removed before the black tin is clean enough to fetch its proper price.

The method employed on a working scale is to roast the ore, and therefore in a vanning assay we must imitate the procedure that would be used on a working scale. The heavy impurities whose removal is assisted by roasting are iron pyrites, copper pyrites, and arsenical pyrites.

The roasting is performed by placing the vanning concentrate in a clay crucible, which is gradually brought to a dull red heat. The mineral is gently stirred, with a clean iron rod, until after about half an hour no more smell of sulphurous acid can be noticed. The crucible is cooled and the contents placed again on the vanning shovel and washed. The oxide of iron and a little remaining sand are now easily washed away. The use of a hand magnet is a help in removing any small particles of metallic iron which may have come off the mortar, bucking board, or tools used in taking the sample.

The concentrate should now be clean cassiterite, unless wolfram is present. This mineral is not altered by roasting, except that the particles will be smaller as it decrepitates on heating.

To ascertain whether wolfram is present, digest the concentrate in *aqua regia* in a covered dish or beaker, so that the acid is nearly boiling for half an hour. If wolfram is present a canary-coloured sediment will be noticed with the cassiterite. If this sediment is seen to be present the digestion must be continued for four hours, adding more acid as may be required. At the end of this time the liquid is cooled and allowed to settle. The clear liquid is poured off the sediment, which is a mixture of tungstic acid and cassiterite.

The sediment is washed free from acid by adding small successive quantities of water, stirring, settling, and pouring off. Tungstic acid is soluble in ammonia, cassiterite is not. Ammonia is added in sufficient quantity to dissolve the yellow sediment, and the contents of the vessel

are filtered through close filter-paper, and the filter washed with water containing a little ammonia. The cassiterite remains on the filter-paper, which is dried, placed in a porcelain dish, and burned off at a low heat. This, after cooling, is weighed and gives us the weight of the purified cassiterite. The solution of tungstic acid in ammonia is evaporated at a gentle heat in a porcelain or platinum dish and ignited, cooled, and weighed.

If the digestion of the vanning concentrate gives no sign of any yellow sediment, wolfram is absent, and the vanning concentrate represents the quality and quantity of " black tin " that would be recovered from the ore under test by the ordinary means of dressing.

The cassiterite concentrates can now be assayed for metal, either by chemical assay (see Appendix) or by the cyanide method.

If the cyanide method is used, it will be necessary to make several vannings, because it is advisable to use not less than 5 grm. for a cyanide assay. To avoid the necessity of spending so much time, it is customary to use chemical assays on the concentrates obtained from low-grade materials.

Cyanide Assay. Weigh out 5 grm. of vanning concentrates, or 5 grm. of black tin as offered for sale, or an equal quantity of the pan concentrates obtained from alluvial ; digest in 30 c.c. of hydrochloric acid for ten minutes, add 8 c.c. of nitric acid, and boil again. This dissolves all oxides soluble in acids. (If wolfram is present much longer boiling is needed.) Dilute and pour away the acid liquor, wash with water, settle, pour off, and dry the residue. Mix the residue with 5 grm. of powdered cyanide, and place this in a pointed clay crucible in which 2 grm. of cyanide have already been placed, cover with 3 grm. of cyanide, and heat quickly to a dull cherry red, and keep at this heat for ten minutes. Hold the crucible firmly in the tongs and tap it carefully on the edge of the furnace, to get the molten globules of reduced tin to unite into a button, and pour into a warmed cast-iron mould which has been black-leaded. After cooling, place the melt in water. The slag will dissolve, leaving the button of tin, and possibly some small beads which have not joined the main button.

Dry and weigh them ; from the weight of the metal we can calculate the percentage of metal in the concentrate.

Assay of Tailings. If it is desired to learn the *total* quantity of tin that is contained in tailings, a chemical method of assay should be employed, but to ascertain what can be *recovered*, it is necessary to make a vanning

FIG. 4. DREDGE PADDOCK BEING EXCAVATED
The building site can be seen being formed by the discharge from the launder
(*Tronoh Mines, Ltd.*)

assay first, and then a chemical assay on the vanning concentrate.

Assay of Concentrates (*Mine or Alluvial*). This may be made by any method. The cyanide method is often employed, but the anthracite method, which was in regular use some years ago, has the merit that it avoids the use of such a dangerously poisonous substance as cyanide.

After careful mixing and quartering, the sample is crushed and dried and 80 grm. are weighed out. This amount should be digested in acid to remove anything soluble, and if wolfram is present it must be removed as described in the cyanide assay.

After washing and drying, the insoluble residue is well mixed with 18 grm. of powdered anthracite, with a little powdered fluorspar as a flux if it is judged to be necessary. This mixture is charged with a scoop into a plumbago crucible, which has been brought to a dull red heat. The crucible is covered, and brought to nearly a white heat for half an hour. After this the contents are poured into a warmed cast-iron mould, and cooled. The button is separated from the slag, which is powdered and panned to recover any small prills. The button and prills are placed in an iron spoon, which has been coated with plumbago, and melted at the lowest possible heat. All dross is then scraped to one end of the spoon, and held back by a small hard-wood stick kept for this purpose ; while the molten tin is poured into a groove cut in a block of marble, of such a size that a little bar of tin is obtained about 4 in. long, $\frac{1}{2}$ in. wide, and $\frac{1}{4}$ in. thick. The anthracite method is now seldom used, but it is included here because it is simple to carry out, and does not need the use of a very delicate balance. It can be carried out on a smith's forge if a proper furnace is not available. It gives a result a little lower than the cyanide assay.

Wet Assay of High Grade Cassiterite.

Weigh up 0·5 grm. of the ore which has been very finely ground in an agate mortar into a spun iron crucible, and mix with about 5 grm. of sodium peroxide, cover with a lid, and fuse carefully over a burner. When molten, remove the lid and rotate the crucible in the flame for a minute or so until completely tranquil. Allow to cool and transfer with the lid to a beaker containing 50 c.c. of distilled water. When reaction has ceased remove the crucible and lid by means of tongs, and wash first with water and then with a little pure hydrochloric acid. Add hydrochloric acid to the assay until just acid and transfer to a 750 c.c. round flask, cool to about 25° C., and gradually add 6 grm. of pure zinc dust, the flask being shaken at each addition. Iron is reduced and the tin precipitated as metal. Now add 50 c.c. more hydrochloric acid, washing in any zinc dust that has stuck to the neck of the flask. This must be done gradually owing to the brisk reaction set up. Heat till the solution is clear, and then

lower into the flask a pure nickel coil, supported on a glass rod passing through a rubber cork fitting the neck and having an outlet tube. Reduce at a temperature just below boiling point for 20 minutes. Remove from the hot plate and cool in an atmosphere of carbonic anhydride in a stream of running water. In the absence of a carbonic anhydride apparatus, this can be done by inserting a small piece of hard white marble in the flask. Remove the rubber cork and nickel coil, and wash the latter quickly with a few c.c. of starch solution, and titrate rapidly with a standard iodine solution until the end point is shown by a distinct blue colour.

The iodine solution is made up by dissolving 16 grm. of iodine in distilled water with the addition of 50 grm. of potassium iodide, and making up to 1,000 c.c. in a measuring flask. The strength will then be such that 1 c.c. is equivalent to about 0·0075 grm. of tin.

The iodine solution is carefully standardized by weighing 0·3 grm. of pure tin filings into a 750 c.c. round flask, and dissolving in 20 c.c. of hydrochloric acid. Fuse 5 grm. of sodium peroxide in an iron crucible for the same length of time as the assay. Transfer to a beaker containing 50 c.c. of water, wash out the crucible, using water and then a little hydrochloric acid, make just acid, and add to the standard. The addition of the ferric chloride formed greatly assists the solution of the tin filings. Continue from this point just as an assay, and calculate the strength of the iodine solution from the c.c. required.

When cassiterite concentrates contain copper, bismuth, antimony, arsenic, tungsten, titanium, etc., it is necessary to separate these elements before fusing in sodium peroxide.

Note. Aluminium may be used in the place of zinc dust for the reduction.

An alternate method of rendering the tin soluble is to reduce the finely divided ore by heating in an atmosphere of hydrogen instead of fusion with sodium peroxide.

CHAPTER V

Underground mining—Compressors, blasting, the use of explosives—Drilling by hand, by air drills—Conveyance of the ore—Mining by adits—Rate and cost of driving—Mining by shafts—Stoping and timbering—Drainage of mines—Ventilation of mines—Open cast mining on stockworks

In the chapter dealing with alluvial mining, it will be noted that the mineral sought for is near the surface and in a soft matrix. Underground mining presents a different problem. In this case a greater outlay is needed to arrive at the ore. The ore has to be mined under conditions much more costly than if it was on the surface—it has to be brought to the surface, the workings must be kept drained and ventilated, the roof and sides supported where necessary, and the work has all to be carried out by artificial light.

All these conditions increase the cost of underground mining over that of surface mining. In addition to these greater costs, there are certain inherent risks in lode mining which we cannot provide against. The lodes may become poor, the mineral may change entirely in character, more water may be met with than was expected, and we cannot prove the values in a lode deposit until considerable outlay has been incurred.

Some idea of the probable mineral contents of untested ground may be deduced from adjoining mines, but only where there is good reason to believe that the strata are continuous and uniform in character.

The method of arriving at the place where the mineral lies varies according to whether the deposit is above or below the general ground level. If above, it can be reached by "adits" or tunnels; if below, it must be explored by sinking in the first instance.

Most of the appliances used are the same in both cases, and it will be convenient to describe them first.

Air compressors are dealt with first because, whether driving or sinking is undertaken, the progress made is so very slow if hand labour only is employed, that it is best to employ compressed air from the start.

Air Compressors. There are several different patterns,

in most of them air is drawn into a cylinder through an automatic valve, and on the return of the piston it is compressed. In a single-stage compressor it is delivered at once into the air main ; in a double-stage compressor the air is compressed to a certain extent in the first cylinder, and further compressed in the second one. In the act of compressing air, latent heat is set free, so that the piston and cylinder would become hot and difficult to lubricate unless a method of cooling were adopted. Water jackets are, therefore, employed, and the cooling water must be taken from a source that will never fail by freezing, and the water must pass through a strainer to exclude leaves and sediment which might block up the pipes or jacket.

A compressor may be steam-driven direct, a steam cylinder driving the piston of the air cylinder with or without a crank and flywheel, or the compressor may be driven from an electric motor, an internal combustion engine, or by water-power. When the compressed air leaves the compressor it is conveyed to its work along an air main. This main is wrought-iron or steel piping, and must be provided with drain cocks to draw off the moisture which will condense. It is customary to have one or more vessels (generally cylindrical with egg-shaped ends) to act as reservoirs. These must also be fitted with drain cocks. When a compressor is feeding drills the compressor is at work continuously, but the drills are used intermittently. The receiver helps to equalize these variations and steady the pressure of the whole system. Before laying an air main every pipe must be brushed out to remove dirt or flakes of rust, and the joints must be made with great care. It is necessary to make them absolutely airtight, as the smallest leaks mean considerable loss of power. There is friction in the passing of air through pipes, hence air pipes must not be too small in diameter, and the distance from the compressor to where the air is going to be used should not be any longer than is essential. (When compressed air can be generated cheaply it has been found profitable to transmit it through pipe lines for a distance of several miles.)

The chief use of compressed air in mining is for the running of drills ; it is also employed for hoists and

winches. The exhaust air from drills enables men to work in dead ends, where it would not be possible otherwise through lack of natural ventilation.

Compressors can be obtained large enough to supply 20 or 30 drills, or small enough to supply one or two. A single cylinder compressor, compressing 100 cub. ft. of free air per minute to 90 lb. per square inch, is sufficient to run two small drills. Such a compressor requires about 20 h.p. to drive it. Compressors must be placed in a building, where they are protected from dust and grit. They should be oiled up every four hours, and great care must be taken that no water condensing out of the compressed air runs back into the compressor, by interposing a receiver fitted with drainage cocks. The distance from this to the compressor should be very short, as compressed air begins to deposit moisture *directly* it leaves the compressor. A good oil must be employed in compressors, not only to secure efficient lubrication, but so that the air, after having done its work in the drills, will be fit to breathe and have no unpleasant smell.

Blasting and the Use of Explosives.

In metal mines the explosive used to-day is generally gelignite. This is supplied in cylindrical sticks about 3 in. long and $\frac{3}{4}$ in. wide. It is exploded by a fulminating mercury cap. In fitting up a charge, a suitable length of safety fuse is cut off with a sharp knife, and one end placed gently inside the cap, which is closed on it with a special pair of pliers, so that it cannot slip out again. A hole is made in the stick of gelignite by pressing a pointed stick into it, the cap and fuse inserted, and the gelignite is squeezed in the hand to retain the cap and fuse in place. If the hole to be blasted is a deep one, two or more plugs of gelignite are placed in it first and then the plug carrying the fuse. The hole is then " tamped " by putting some clay, or earth, into the hole over the charge, and very gently pressing it down. Force might cause a fatal explosion, so that ramming dirt down on the charge with a bar must never be allowed. In " downward holes " the tamping may be done by simply filling the hole with water, though this is not quite so effective as tamping with clay. It has, however, the advantage that if the charge fails to

explode, it can be withdrawn. A tamped charge which fails to explode must not be withdrawn, but a fresh hole must be bored alongside, and if on firing it the first charge does not explode, the charge must be searched for among the broken rock until it is found. Gelignite must be stored in a licensed magazine, built and maintained according to regulations, and carried into the mine in the jacketed cans sold for this purpose.

Gelignite which has gone hard, owing to cold, must always be softened in the official cans ; it must on no account be used unless soft.

Gelignite is obtainable to-day which does not harden in winter.

Detonators, or " caps," are small copper tubes closed at one end containing fulminate of mercury. They are supplied in tin boxes. These boxes and the individual caps must be handled with the *greatest care*, a jar may cause an explosion. A detonator exploding in the hand would certainly cause the loss of some fingers, if not the whole hand.

The old careless practice of biting the detonator to close it on the fuse is extremely dangerous, and it is compulsory to have and use the proper pliers for closing the caps on the fuse. The detonators are sent out filled with a short dry sawdust (hard wood sawdust). On an occasion within the writer's experience a miner about to make up a charge turned the cap upside down to pour out the sawdust, which usually falls out at once. A rather coarse sawdust had been used and it did not pour out as usual. The miner tapped his hand on his knee, and this very slight shock was sufficient to explode the cap with serious injury to his thumb and three fingers. This is mentioned as an instance of the great sensitiveness of detonators, and particularly as a warning against dropping a box of them. Detonators should never be handled by anyone who is not aware of their sensitiveness. They must not be stored in the same magazine with gelignite, but kept locked up in small quantities in a place where they are not exposed to damp or heat, where they will not be exposed to shocks, and cannot get knocked over. If caps get damp no attempt should be made to dry them ; a fresh supply should be obtained.

Drilling by Hand. This is very slow, laborious work, and can only pay with cheap native labour. If for any reason hand drilling must be employed, the chief point is to supply the drillers with plenty of well-tempered drills of convenient lengths. The " bit " of each " following " drill should be slightly smaller along the edge than the one before. The number and depth of holes that can be drilled naturally varies according to the hardness of the rock. From 4 ft. to 6 ft. per man per shift may be regarded as an average in hard rock. Where deeper holes can be " jumped " with a long drill, as in open cast mining where the holes are all downward, a greater footage can be made.

The " pulp " from the holes, which are kept wet by pouring in water, is drawn out by a scraper, a light iron rod hammered up at the end to form a small cup or scoop. It is often convenient to wash some of this pulp, to see what mineral there is in the rock that is being drilled.

Drilling by Air Drills. Air drills are made in a variety of patterns ; they vary from light drills that can be carried about easily and held in position by hand, to heavier types that are worked off a bar or tripod or mounted on a wagon. Light hand hammers are very satisfactory for downward holes ; when used for uppers and horizontal holes the vibration is more felt by the operator. They are used chiefly for stoping. For driving ends heavier drills are wanted ; they are mounted on a heavy column, screwed tight from floor to roof, or on bars secured to this column. With an air drill a man can drill from four to ten times the number of feet that he could by hand. Air drills are to-day a necessity in economical mining, both for the advantage they give in quick drilling, and in keeping the atmosphere free from an excess of fumes and carbonic acid gas. Air drills are only actually at work for a portion of the shift ; the changing of the bits, charging holes, blasting, and moving to fresh positions take up more time than the actual drilling ; while a drill is not working the compressor is restoring the pressure all the time, so that two drills can be run on the air that would only supply one if it were at work continuously. In purchasing drills or compressors, if they are second-hand, care must be taken to see that the pistons and

cylinders are not scored, for in this case there would be great loss of power. Unless drills and compressors are in practically new condition, it is not advisable to purchase them second-hand. In using air drills, the miner must be careful not to let either end of the armoured hose, which connects the drill to the air main, fall into the dirt when he has occasion to disconnect, or dirt will be carried

FIG. 5. VIEW OF A DREDGE SHOWING SCENERY IN THE NEIGHBOURHOOD OF A TIN MINE
(Tavoy Tin Dredging Corporation)

into the moving parts of the drill to its great injury. If an air drill is treated like a sporting gun, that is to say, kept clean and oiled up frequently, its life and efficiency will be far greater than if it is neglected.

In drilling rock it is absolutely necessary to keep a water spray playing on to the hole. Dry drilling produces clouds of sharp dust very dangerous to breathe, and it is contrary to the mining regulations in all countries to drill without a water spray. Hollow drill steel is now much used, the water being forced through the drill itself.

Conveyance of Ore and Rock. In driving, a tram line

should be put in from the start ; barrowing is exhausting and costly. The best rails to use are 12 lb. to 16 lb. to the yard ; they should be bent as required with a " rail bender " to a correct curve for coming round corners. It pays to have tram roads truly laid and properly maintained.

The tram wagons used are sometimes too heavy and cumbrous ; light wagons can be made by buying the wheels, axles, and bearings, and building a wooden body, if end tipping wagons are required. The weight of a wagon to carry one ton need not exceed 6 cwt. It is essential to see to the regular oiling up of the bearings, which should be done two or three times a shift. If they are soft metal bearings they can be replaced when they wear by turning the wagon over, and having placed clay to retain the molten metal, and having adjusted the axle at the right height, molten soft metal is poured in to form a fresh bearing. Roller bearings properly cased in are a great improvement on the old patterns of bearings ; they cost more to begin with, but are a real economy. The cost of tramming has often been much higher than it ought to have been, but was probably not regarded as important when wages were low. Where a drive is large enough to use a pony, and the distance is considerable, it is a great saving of labour. For outdoor work paraffin tractors are excellent. For conveyance of ore, where the ventilation would not be suitable to use these, electric tractors, such as employed for luggage trucks at railway stations, would be very useful. They carry their own accumulator, and only require charging during meal times and at night. Whatever method is used the cost should be calculated, and continuous efforts made to reduce it. When tramming is done entirely by manual labour, and the distance is great, it may need one trammer to every two miners, and this is a wasteful proportion.

1. Mining by Adits.

Lodes may outcrop on flat ground, or on the top or sides of hills. If they are traceable near the base as well as on the upper portion of a hill, they can best be explored and worked by an " adit," or tunnel, driven in from the lowest point. There is a great difference in the expense

of mining by shafts and by adits. Shafts are expensive to sink : the deeper they go below water level and the more the workings are extended, the greater the amount of water that will have to be pumped, and pumping is a never-ending expense. An adit costs must less to drive per fathom, and there is no pumping to be done. It is, of course, not possible to use adits everywhere. They are only of service in a hilly country, where one can drive in at a low level, so that when the adit reaches the point aimed at there is a considerable height of " backs " above it. Adits provide a means of thoroughly and properly exploring an area by cutting all the lodes that run across their path, if they are driven at an angle to the run of the lodes. In this way " blind lodes " (that is, those which do not outcrop at surface) are discovered and tested, or if the adit is driven along a lode, any neighbouring lodes (which are usually parallel to it) can be intersected by cross-cutting out from the adit at right angles in both directions, when it has reached the principal mineralized portion of the mining set.

Before driving an adit one has to decide whether to drive in *on* a lode, in which case ore is being got out at once, or whether to drive in barren rock to *cut the lode at an angle*. The distance to be driven, the amount of " backs " that will be got, and whether there are other lodes to be explored as well, will assist in making this choice. It is always attractive to drive in on ore, but if there are several lodes to be tested, a cross-cut adit will probably be preferred. The adit should rise not more than $\frac{1}{4}$ in. in the fathom ; this allows the water to drain out freely. A steeper rise is quite unnecessary, and makes it hard work to bring in the empty wagons. For a long adit a still slighter rise may be advisable. In driving an adit it is necessary to provide at the outset for a continuous supply of fresh air. One can admire the energy and perseverance of the " Old Men " who drove many scores of fathoms when compressed air was unknown. They used to place large bellows, worked by hand or by water wheels, at the mouth of their adits to drive in fresh air, and they had to make air shafts for ventilation at intervals. Such air shafts are not needed to-day, as the use of a little compressed air enables us to blow away the smoke of a

blast from an end in a few minutes, and the waste air from drills provides fresh air all the time they are at work.

The cost of driving adits varies chiefly with the hardness of the rock, the size of the drive making rather less difference than would be expected. It is usually sufficient to drive them 7 ft. by 5 ft., for a single track of rails ; if a double track is desired they should be driven 7 ft. by 7 ft. Compressed air first came into use about sixty-five years ago ; prior to that all driving was done by hand. Robert Hunt speaks of adits as " costly in construction and slow in execution," the cost of driving an adit at the time he wrote (1878) varied from £2 10s. to £10 a fathom, but he fully recognized their value both for exploration and as a means of lessening the cost of heavy pumping. Hunt gives an interesting account of the work accomplished by the drills introduced in his time. Since he wrote the efficiency of air drills has been very greatly improved.

At the present day *driving by hand*, with white men at 8s. per shift, may cost from £6 a fathom in easy ground up to £20 in very hard rock, with an average of about £10 to £12, and it would be necessary to provide means of ventilation. Driving with air drills, these costs can be greatly reduced and the rate of advance is much faster. Working three shifts, an advance of 100 ft. a month has been exceeded in ground of average hardness. If ground is so soft as to need close timbering, or very hard, the rate of advance may be much less. Timbering in soft rock needing support is done by setting stout " legs " at proper intervals with " caps," or " bearers," placed above them, and " laths " (poles or rough planks) reaching from cap to cap. In the case of adits that are likely to be used for long periods, the use of timber should be avoided. It may be cheaper in the first instance, but wood rots in the course of time, and it is better to build up dry stone, or stone and concrete arches where necessary. In Cumberland many adits can be seen very ingeniously arched with dry stone arches, which have been in place for over 150 years, and appear likely to keep in position indefinitely.

2. Mining by Shafts.

The chief difficulty that attends the sinking of trial shafts is that of keeping them unwatered and ventilated.

There are, of course, some places where shafts can be sunk for many fathoms before water is met with, but in most cases ground water is only a few feet below the surface, so that provision for pumping, or baling, should be made at once directly sinking is decided on, to avoid delay later.

A trial shaft should be carried down on the lode that is being tested, and followed only while it is vertical. The older workers used to keep in the lode all the time, and if it dipped much they had great difficulties in having to haul dirt in a crooked shaft. A crooked shaft is of no use afterwards except for ventilation and as a ladder-way, so that it is better to sink vertically from the start. If the ground is loose, a strong collar should be put in until firm rock is reached. Provision must be made for ventilating, for when a small shaft reaches 30 ft. to 40 ft. in depth it is liable to become very stuffy at the bottom, and the fumes after blasting take a long time to clear away. For this reason it is best to put in a small compressed air plant from the start. A compressed air winch will save a great deal of time in hoisting the dirt, and with an air drill the rate of sinking will be two or three times that of hand drilling. The cost of sinking a trial shaft depends on its size, the nature of the rock, and the cost of labour. Trial shafts may be made as small as 6 ft. by 4 ft., and if provision is made for a compressed air drill and an air hoist, they may be put down in average rock at the rate of 18 ft. a week ; the cost would be about £2 a foot down to 100 ft., rising to £3 for the next 100 ft.

In re-opening an " Old Men's " shaft, care must be taken that there is not an accident, owing to the ground giving way or the collar of the shaft running in. Poles or rails should be laid across, and the dirt removed carefully until the solid rock is reached. Often the shaft is collared over, at a depth of a few feet, by two or three large stones ; these may be loose and ready to fall away. When men are at work where ground may subside, they should have a rope tied under their armpits, and this rope should be secured to a post. After the top of the shaft has been uncovered, the collar should be rebuilt, properly fenced and provided with a door, and locked while work is not going on. Old shafts were usually circular and lined with

stones, neatly and tightly packed together, until solid rock was reached. The old workers generally had one shaft for their ladder-way and pumps, and another for hoisting ore. Shafts nowadays are sometimes rectangular, sometimes circular, and are divided off from top to bottom. In all civilized countries there are regulations requiring that the cages in which men travel must be provided with "safety catches," designed to grip the guides in the case of the hoisting rope breaking; an indicator in the engine room shows the position of the cage in the shaft, and there is a system of signalling to inform the driver whether the cage is to be raised or lowered, and at what level it is required.

Ore is raised by running the wagons into the cage and hoisting them to the surface, or skips are filled below, and these skips tip into bins or wagons at the surface. In re-opening an old shaft, if it is not large enough to take a cage, it should be enlarged and room made for pumps and ladder-way, unless there is another shaft that can be used for this purpose. In all mines where there are two shafts, they should both be kept in order to provide two separate means of exit, as a precaution in cases of emergency. It is not advisable to spend money in enlarging an old shaft unless it is vertical.

Stoping. The method of excavating ore from lodes is termed "stoping." Two methods are in use, overhand or back stoping, and underhand stoping.

"Overhand stoping," or working on the ore in the roof of a level, is commenced by putting up a rise in a level, and working out a sufficient quantity of the lode until there is space to erect a platform on which the miners stand to work. The ore is allowed to drop into chutes, placed in the roof of the level, so that it can fall from them into tram wagons. These chutes are built of rough timber and furnished with "stoppers," or sliding doors, which retain the ore in the chute, till the trammer brings his wagon below it and lifts the stopper. In overhand stoping the ore that is to be sent to the mill is thrown into the chutes, and rock that is unavoidably broken is kept in the stope, and serves as a platform for the miners to stand on. In this way there is no considerable cavity overhead, and hence this is the best way to work ground

where the walls are not naturally hard enough to be secure.

" Underhand stoping " is done by working out the floor of a level ; the ground is worked out in a series of steps. This leaves an open cavity overhead. Stopes may be left unfilled if the country rock is hard, but where there is any danger of the collapse of the roof or sides, it is necessary to leave some poorer sections of ore standing, or to place timber across and fill in with stones to keep the walls and roof from falling. Underhand stoping is very seldom done, and is much slower than overhand stoping, because of the extra handling of the ore. The amount of lode stuff that can be broken by men stoping varies very much with the width and hardness of the rock, and whether they are working by hand or with air drills. By hand it may be no more than from half a ton per man up to two tons ; with air drills probably three times as much.

Drainage of Mines. The drainage of adit mines is accomplished by natural means, and costs nothing. In shaft mines the cost of pumping may swallow up a large part of the profit. Hence there is a great advantage in having natural water-power for pumping and other operations. Just as an alluvial mine can be worked cheaply when a large supply of water under a natural head is available, so in the case of lode mines water-power is a great assistance to cheap production, and may save a mine from having to close down in times of low prices. When coal was cheap and mines were shallow, the cost of pumping was not felt as it is now that coal is dear, and we cannot reckon on getting cheap coal in the future.

Water is, of course, needed at surface for dressing, but steps should always be taken to do the essential pumping as cheaply as possible.

The water that enters a mine usually does so through certain well-defined fissures, and not equally at all points. It is partly the rain-water that has fallen directly on to the immediate area, and partly that which comes in laterally from outside the area. Of the rain that falls on a given area, about one-third finds its way under ground, but it does not penetrate very far in a tight close-grained rock unless there are broken floors or fissures. All

lodes are natural fissures, and when these lodes are wholly or partially stoped out, they become actual water channels, which allow the water to travel down from the surface into the workings. If the shafts are sunk in a porous or much fissured rock, it is to be expected that water will enter unless the shaft is concreted. The François method of sealing off water, by forcing in cement under pressure, has proved a great assistance in lessening unnecessary pumping. It would appear that more could be done in this direction ; for instance, if the floor of the main adit to a mine (in those cases where the adit is some appreciable depth) were concreted, and all the drives connected to it were treated in the same way, much water could be prevented from travelling down to the lower workings.

Cornish Pumps. These have been used for many years, and for reliability and economy have not yet been superseded. Until recently they have always been driven by water or steam-power, but they can be operated by suction gas, oil engines, or electric power. A Cornish pump should not be driven too fast ; its speed may be from three or four strokes per minute up to ten or twelve, but it should not be worked any faster than this, or the strain on the moving parts will cause additional wear and tear. They are made as small as 6 in. and as large as 20 in. (diameter of cylinder), and the stroke may be several feet long. The use of large pumps means very heavy main rods and strong fittings, and they require the services of six shaft men (two per shift) constantly to see that all is in order. It is not possible to pump beyond a certain height in one stage on account of the pressure of water in the rising main, so the pumping is conducted from cistern to cistern, and the pumps on the main rod are alternately lift pumps and plunger pumps. In order to obviate the need of an enormously strong and heavy main rod, electric pumps have been used with varying success. The Cornish pump has stood the test of time and is very reliable. It has the advantage that it can be restarted after a stoppage when the shaft may be full of water, and if the valves are in order it may be very little the worse for having stood for some time. Quite possibly the latest patterns of electrical pumps could do the same, but there is naturally a feeling of security regarding the

Cornish pump, on account of the reliable service it has given under rough conditions, and its rugged construction, which enables it to stand up to work which might be too hard for a machine of more delicate construction. In deep mines, and even in some shallow mines, the cost of pumping is a serious item of expenditure unless there is water-power to do it with. The cost of pumping may be as low as under a shilling per ton of ore raised, or over four shillings.

Ventilation of Mines. The ventilation of mines is a matter of great importance for the health and efficiency of the workers. There are four things in badly-ventilated mines which are dangerous to health—

1. Dust, particularly that consisting of sharp particles of rock.
2. Products of explosives, particularly carbon monoxide.
3. Hot and saturated air.
4. Low percentage of oxygen and excess of carbonic acid gas.

1. Sharp dust is the chief cause of miner's phthisis. It is most important that no holes should be drilled dry. Water sprays are compulsory, and every care should be taken to enforce their use.

2. The gaseous products of explosives produce headache and general discomfort, and are actually injurious unless well diluted with air. The best way to get rid of them would be to supply air under a pressure of a few ounces, and allow it to be used freely at the men's convenience. Compressed air is usually too expensive to liberate it freely as an ordinary means of ventilation.

3. Hot saturated air checks the evaporation from the skin that is absolutely necessary to steady exertion and to health. Men can work steadily in warm air if it is still able to take up more moisture, but when it approaches the saturation point their ability to work falls off greatly, and continuous exposure to hot saturated air is injurious. It is, therefore, advisable to suck out warm moist air, so that fresh air shall descend to fill its place, or fresh unsaturated air should be sent underground in pipes.

4. The danger due to lack of oxygen, or excess of carbonic acid gas, is chiefly in dead ends, stopes, rises,

and winzes. If the flame of a candle goes out, or shows the well-known signs of doing so by the flame elongating and beginning to leave the wick, the place is unsafe. A man should never go alone into disused workings, and if he is using an acetylene hand lamp he must carry a lighted candle as well.

The candle flame will show whether the air is safe or not, whereas an acetylene lamp will burn in an atmosphere which is dangerous to man. An electric hand lamp is, of course, not influenced by the condition of the air, so that if an electric hand lamp is used, a candle should always be used at the same time in a place which is at all doubtful. Bad air is not necessarily to be found in a low part of the workings, it is sometimes met with in the upper part of a stope where one might not expect it. As a matter of business, it is a mistake to allow any part of a mine to be badly supplied with air, for the work done under such conditions will cost more than if fresh air is supplied.

Open-cast mining, or quarrying for tin ore, has been practised in several countries. The Anchor Tin Mine, in Tasmania, used to crush 350 tons a day, and with a price for tin much lower than it is at the present day, paid working costs with a recovery of no more than 3·5 lb. of black tin to the ton. The cassiterite in this mine was disseminated in small groups of crystals in a fairly soft granite. The mine had the advantage of a good water supply most of the year.

The Mount Bischoff Tin Mine, in the same country, is working to-day as an open-cast mine on a comparatively low-grade tin ore. Instances in England are Carclaze and Mulberry ; at the latter mine the recovery used to be from about 5 lb. to 7 lb. of black tin to the ton.

At Wheal Prosper, which is at present being worked on a small scale, the recovery for many years (without slime plant) was 3·5 lb. per ton. This mine is a remarkable instance of low working costs. The cost of breaking the ore (a fairly soft killas) is less than a shilling a ton, tramming is about 8d., stamping by water-power about 6d., while dressing and repairs are about 10d. These costs show how cheaply some open-cast deposits can be worked, and if there were facilities for working them on a *large*

scale, they would pay well to-day. Unfortunately, we are not well off for water-power in this country, so that the practice in the past has been to mill to the full extent in winter and hang up part of the mills in summer. There are other open-cast deposits, abandoned in times of low prices, which might pay to work to-day. It is chiefly a question of cheap power, and of the local conditions being favourable for the treatment of large quantities.

CHAPTER VI

Milling and dressing—Site for a mill—Ore selection in the mine and after washing—Comminution of the ore—Different types of mills—Cornish rolls—Rock breakers—Ball mills—The dressing of tin ore, old and modern methods—Buddles—Shaking tables—Slimes and their treatment—The dressing up of concentrates—Degree of purity to which tin should be dressed up to for sale

Selection of Mill Sites. A site for a mill should, if possible, be chosen where there is sufficient space and fall for the various operations to be conducted in such a manner that the ore passes by gravitation through all the processes down to the final stacking of the tails, and has not to be lifted or returned during any stage of the treatment. It is only in the case of a few mines where the space and levels at command are what can be termed ideal for this purpose. A long piece of sloping ground is wanted, so that the various appliances can be laid out in steps or terraces.

It is partly due to the fact that many mines were cramped for room in their dressing arrangements, that their tailings have been worth retreating at a later date, or that streamers situated below them have found it profitable to work their tailings. It sometimes happens that there is very little choice of sites for a dressing plant ; but these remarks are inserted to draw attention to the importance of choosing a good site wherever it is possible to do so. It is easy to conceive of a case where it might pay to convey ore to some distance, if by so doing one could treat it at a place where there is suitable space and fall to lay out floors as one would like to have them, rather than be content with a cramped site simply because it is close to the top of a shaft, or the mouth of an adit.

Ore Selection Underground and Above-ground. When wide lodes are being stoped, there is not so much country rock being broken as when the lodes that are being worked on are narrow, but there is nearly always a certain quantity of waste rock mixed with the ore. When the proportion of waste rock is considerable, it is picked out as far as possible, and retained underground. It is not always easy to distinguish underground, by artificial

light, what ought to come out and what ought to be retained, as the ore is often covered with mud, so that selection cannot be carried out very closely. Only the large pieces of waste rock should be retained underground, and anything at all doubtful should come out.

In old-fashioned plants it was customary to let almost everything go into the mill. To-day it is realized that *anything that does not contribute tin helps to carry it away.*

Ore Selection Above-ground. Ore should be washed as it comes from the mine and passed over a picking belt, or picking table, before it goes to the mill. One must remember that the country rock itself sometimes carries tin, so that what is supposed to be barren rock should be tested frequently, to see that one is not discarding anything of value. In a small plant, where there is no picking belt, it is convenient to tip the wagons as they come from underground, on to a long grizzly, and turn a hose on to the ore that remains on the grizzly. One can see at once what is ore and what is addle when it has been washed clean. It is, of course, impossible to pick over the small pieces of ore, so they should go into the mill at once. By having a long grizzly to tip the ore on to, and a low tram wagon beside it, with its top just level with the top of the grizzly, it is easy to pick out the addle and tram it to a dump. The washing of the ore also makes it easy to pick out any fragments of wood that have come out from underground ; it is important to pick them out, for if they get into the mill they blind the screens, and it is important that the screens should be kept quite clear at all times.

Comminution, or Crushing of the Ore.

There are different ways in which ore may be reduced to the required degree of fineness, but to obtain the best result (the highest recovery of mineral) the same general principle must be observed, whatever apparatus is used.

The object in breaking the ore is to set free the particles of mineral from the gangue in which they are enclosed, and to accomplish this without breaking the mineral itself more than can possibly be helped, for the less the mineral particles themselves are broken the better the recovery will be.

FIG. 6. DREDGE PONTOON READY FOR LAUNCHING
(Malayan Tin Dredging, Ltd.)

FIG. 7. DREDGE PONTOON BEING LAUNCHED
(Malayan Tin Dredging, Ltd.)

It is, of course, quite impossible to avoid breaking some of the mineral particles more than they ought to be broken, but we must keep it constantly in mind that the comminution of the mineral itself is the chief thing we have got to avoid, as it is the principal cause of loss of tin in dressing. In the very early days of mining it is probable that no crushing was done at all, because the old miners were able to get their supplies from alluvial where the mineral was all free, and not attached to stony particles. As this became scarcer, they would have had recourse to shode stones and the material dug off the backs of lodes. Crushing is still done abroad, in some places by rubbing ore down on a flat stone. In Cornwall and Devon we find to-day some of the old mortars used by the ancients, in the form of large granite blocks, with hollows in them in which they pounded down the ore. At a much later date they began to use stamps. The early type of stamp mill consisted of baulks of timber shod with iron, which were raised by pegs fastened to the axle of a water wheel. Such wooden baulks, shod with iron, are used to-day in cases where the ore is very soft. At a later date the wooden lifters were replaced by wrought-iron, and the stamp heads were made heavier. Cornish mills are not made to-day, but there are still many in existence, and when driven by water they are probably the cheapest means of stamping that exists, though, of course, their capacity is very small compared with the modern types of stamp mills.

The Cornish stamp mill consists of a heavy cast-iron axle, which operates (as a rule) 16 head of stamps. The stamp head in this case is a rectangular block of tough grey cast-iron, with a hole cast in one end into which the stem, or lifter, is secured by wedges. The stem works up and down in cast-iron guides, the upward motion being produced by the lifting action of a cam, which is inserted in the axle and engages with a tappet on the stem, while the downward motion is due to gravity.

In a Cornish mill there is not often any die for the head to beat on to ; the heads generally beat on to a bed of granite, which is formed by throwing hard pieces of granite into the mill until a tight bed has been formed, but it is better to use dies, as the capacity of the mill is

greater if they are employed. The cost of stamping with a Cornish mill is very small. If it is driven by water, it may not exceed 2s. a ton for attendance, repairs, and maintenance. The wear on the stamp heads is from 1 lb. to 2 lb. per ton stamped ; it depends on the hardness of the ore and the size of the pieces fed into it. The grates formerly used were made of punched iron ; these last longer than woven screens, but the pulp does not come away through them as readily as with a woven screen, so that there is a greater production of slimes with punched grates.

Californian Stamp Mills. The chief difference between this pattern and the old Cornish mill is that in the Californian mill the stems and heads are round, and are arranged so that there is a partial rotation each time the stamp is raised ; this distributes the wear and tear. In this way the face of the stamp remains fairly flat, while in the Cornish heads there is a tendency for the heads to wear most at the back where the ore is fed in, and to put this right it was often necessary to stop and reverse the heads. The Cornish mill crushes about one ton of *average* ore per 24 hours ; if the ore is very soft considerably more can be put through. The total weight of stamp head and stem in Cornish stamps is about 6 cwt. ; they are nearly always made to a standard size.

Californian stamps are made of different weights, up to 20 cwt., their capacity is about three to four times that of a Cornish stamp. In all types of mill the heads are not all raised together, but in a regular rotation, so that the strain of raising them is evenly distributed throughout the revolution. The number of times that the stamps fall per minute is important ; if they are worked too slowly there will be needless sliming of the mineral, because the pulp stays too long in the mortar box, and in addition the output is reduced ; if the speed is too great, there is a danger of the cam striking the next lifter before the stamp has had time to fall.

The Nissen stamp is an improved form of Californian, with a large grate space round each separate head and a large capacity ; as the pulp can get away freely, the formation of slimes is kept to a minimum.

The Holman pneumatic stamp has a very large capacity.

It is made in a variety of sizes, from small stamps suitable for prospecting, up to sizes which have a capacity of several tons per 24 hours. This is probably the most efficient stamp in existence.

Rock Breakers. Stamps were in operation long before rock breakers, and even after the introduction of rock breakers the spalling of ore by hand was continued when wages were low, or where there was poor lode stuff to be picked out. Rock breakers to-day have been brought to a high degree of perfection, so that with quite a small power consumption they are capable of crushing large quantities of hard tough ore. They are made in all sizes, from little ones fitted for sample crushing, up to large machines taking rocks of a ton weight.

The cost of running a rock breaker naturally varies with the hardness and toughness of the ore, the quantity put through, and the cost of motive-power. It may be taken as varying from 3d. to 8d. per ton, including attendance, oil, replacements, and motive-power. With a very hard sharp ore the jaws wear rapidly. Most patterns of rock breaker consist of a very strongly constructed frame work, in which there is a pair of jaws, one of which is movable. The movable jaw is caused to advance towards, and recede from, the fixed jaw, and also has a slight up-and-down movement. The apparatus is fitted with a heavy flywheel, or pair of flywheels, so that it may run steadily instead of in a series of jerks. The wear and tear on the jaws is great, so they are made of a special steel alloy. It is most important never to let pieces of metal get into a breaker, as if they do not throw the belt off something is likely to be smashed. Another type of rock breaker is made, known as the "Gates," in which the gyratory motion of a steel rod breaks the ore by forcing it against a steel cup.

Cornish Rolls. So far, rolls have hardly ever been used on tin ore. They consist of two heavy cylinders placed near together, having plain or corrugated faces ; one roll is fixed, the other can be adjusted to the desired distance from the fixed roll. Revolving them at different speeds was formerly tried, but it was not found an advantage to do so. Rolls cannot take large pieces of ore, and are not used for very hard ore or for ore needing fine crushing ;

they are suitable for moderately hard ores such as copper, lead, and zinc.

It is customary to-day to make them with a renewable shell, or casing, of a specially hard and tough steel alloy. Rolls are apt to wear unevenly, and when this happens some of the material escapes only partly crushed. They have the advantage that they do not produce slimes as much as stamps do, for the crushed ore escapes at once and does not remain to get repeated blows as it may do in a stamper mill. If rolls are used it is easy to return the oversize, and there can be no doubt that on a *soft tin ore* requiring coarse crushing only, rolls would be very useful, and probably better than stamps. They would have to be fed from a stone breaker set to crush very closely, as they do not take a feed of over $\frac{1}{2}$ in. material.

Ball Mills. These were evolved from the original Michell and Tregonning pulverizer, which is still largely employed for sand grinding. This pulverizer is used on sands and on roasted material ; it consists of a wide cast-iron tube partly filled with scrap-iron, or iron rods, or balls, or hard pebbles. The material to be ground is fed in at one end through a hollow axle with water, and the ground material escapes in the same way at the other end. An ordinary sized pulverizer, say, $2\frac{1}{2}$ ft. in diameter by 8 ft. long, requires about 3 h.p. If it is used on a hard sharp sand it may be worn through in a period varying from six to twelve months, whereas if used on burnt concentrates it may last three or four years. Pulverizers are driven by cog wheels off a water wheel, or other motive-power, or they may be driven by putting a belt round them.

Large ball mills and tube mills are worked on the same principle ; they have a false lining of steel plates which is renewable, and they are partly filled with steel balls or hard pebbles.

The Hardinge mill is conical in shape ; it is made in a variety of sizes up to very large ones, which have a very large capacity. Steel balls of different sizes are used in them. It is possible that they might be more suitable than stamps for some tin ores, though their first cost would be higher.

The Dressing of Tin Ores. The older methods of dressing tin ores are well described and illustrated in Pryce's

Mineralogia Cornubiensis, and in a small testing or temporary plant, strips and buddles can still be employed with advantage. The custom was to allow the pulp from the mill to flow into a strip or tye furnished with stoppers ; sands settle in the tye while the slimes flow through into a slime pit. In the tye three products are made ; the richest material settles at the head, and is dug out and treated separately, the " middle head " is also treated by itself, and so are the tails. In a poor ore the tails would contain so little that they would be discarded.

Another method of treatment was to stamp direct into a large buddle of which there were three, so that one was being filled while another was being emptied and the other was in reserve. The buddle is a very simple piece of apparatus, consisting of a pit or pond from 15 ft. to 20 ft. in diameter, with a central head. There is a spindle with a step bearing in the middle of this head, to which are attached four arms that rotate slowly. From these arms are hung brushes, which trail lightly over the surface of the mound of sand which forms in the buddle. Some buddles have a revolving cast-iron centre head, which just covers the solid centre of the buddle. The pulp is delivered from a feed box (or straight from the mill) along a launder to the middle of the head of the buddle ; it flows over it and down on to the floor of the buddle, where it spreads out into a thin layer that gradually increases in depth as the buddle fills. The richest particles settle first nearest to the centre, the particles which are less rich travel a little farther down the buddle, and the tails form the outer ring, nearest to the outside edge of the buddle. In working a buddle, to get proper results, it is essential that the feed shall be regular, and that the water shall be properly proportioned to the solid matter, and that the level of the tail water shall be kept at the right height. In particular we have to guard against " cutting," this is, the formation of channels in the surface of the sand mound. Some experience is needed to avoid this and to get good separations. When the buddle is full, the flow of pulp is diverted into another buddle, and the one that is full is allowed to drain for an hour or so by taking out the stoppers and letting the tail water escape. The buddle is then marked out by drawing rings on the mound

of sand, after testing with a vanning shovel, to decide which part is good enough for " heads," " middle heads," and which can be discarded as " tails." The heads are wheeled out for retreatment, so are the middle heads ; if the tails are poor they are thrown away.

A convenient plan is to have a gutter round the outside of the buddle, into which a stream of water can be turned ; the tails can be quickly shovelled into this and washed away, instead of having to wheel them away. The gutter may be arranged to run into a long strip, in this a little tin will be caught, and it can be saved by skimming it every two or three days.

A smaller type of buddle without any revolving arms, called a " dumb buddle," is often used, and on suitable material it gives excellent results. In this pattern there is no centre head, and no sweeps to assist in keeping the surface even, so that it is not possible to use large dumb buddles as they would " cut," and they cannot be used for coarse sand. For fine-grained material they answer very well ; they are chiefly employed to receive the pulp from pulverizers.

Modern Improvements in Tin Dressing. While the apparatus mentioned is sufficient for a simple plant, there are several modern improvements which increase the extraction and reduce needless labour. The older workers did not understand the great advantages of classifying the pulp into the various sizes as it is realized to-day. Classification is the separating the pulp into classes so that the grains of mineral and sand are, as nearly as it can be accomplished, the same size. This sizing is done by the action of water ; in the first case the slimes are separated from the sands by an upward current of water, and then the sands are separated into two or three or more sizes. They are dealt with on shaking tables. There are many different patterns of shaking tables, all of which have their merits, some are designed to work on coarse material, some on fine ; experiments may be needed to decide which table is most suitable for a particular ore. As an instance of one which has a large capacity, and will work well on a coarse material, the Record table has been used with great success on coarse tin sands ; for sands of a finer description James tables and Whilfley tables are

much employed, and there are many others which have been used with excellent results. All shaking tables have many features in common; they receive their feed at one end and the pulp travels towards the other end, being subjected to the action of a regulated stream of washing water during its journey, as well as to the motion of the table.

As a rule three products are made: the tails which flow over the side of the table, the middle head which is taken off between the tails and the head, and the head itself which is caught at the end of the table. There are metal slides, or cut-offs, whereby the size of the head and middle head can be regulated. There are also other adjustments which can be made, such as the rate at which the table can be vibrated, its pitch from end to end, and its sideways tilt. For a light sand the fall from end to end need not be great, while for a heavier sand it must be increased. In such a case it will probably be necessary to give an increased sideways tilt as well.

There is a very simple and efficient table, known as a "Rodda" table, which is made locally in Cornwall, and is somewhat on the same lines as a Rittinger bumping table. It is actuated by a cam and bumps against a post. It requires less than $\frac{1}{2}$ h.p., and is light enough for two men to turn it over. The top is covered with lino, and the riffles are straight for the greater part of the length, and somewhat curved at the head end. Its capacity is about eight to nine tons per 24 hours. The writer believes that several of the tables that are advertised will deal with more material than this, but it is always a great mistake to overload any kind of table, and that to get good results they must be fed with a uniform material and clean wash-water. They cannot be expected to give satisfaction unless they are set on a perfectly sound foundation, and run as directed by their makers and kept in proper adjustment. If they are kept standing for any time they should be protected, as otherwise valuable tables may very soon be rendered useless.

Frue Vanners. These have been widely used and have undoubtedly great merits, but it would seem that equally good results can be got from shaking tables, and Frue vanners only produce two products—heads and tails—

whereas there is generally a middle product that needs to go to a pulverizer. There are more moving parts in a Frue vanner than in a shaking table, so that the expense of keeping them in perfect order would probably be greater. It is very important to protect the rubber belts from cold, or they may become hard and cannot be got into a pliable condition again.

Tin Slimes and Slime Treatment. With all the care possible we cannot avoid making some slime tin when a tin ore is stamped. All ores slime more or less, but as the other base metals are not so valuable as tin, less attention has been given to the recovery of the slimes of lead, copper, zinc, etc. The amount of slimes produced in treating a tin ore depends partly on the original size of the tin particles in the matrix, whether they are well crystallized or of a concretionary nature, and very much on the care that has been given to the comminution of the ore. The use of a grate that is too fine, and a slow speed of stamping, are sure to produce more slime tin than if the mill ran at proper speed, and the screen was of a proper size to let the pulp escape the moment the particles were the right size.

Slimes are treated by first allowing them to settle in pits, or sent direct over "ragging frames" or "round frames." Slimes are removed from pits by a series of water jets which break the slime up again and then elevate it, if required, by a dipper wheel. Ragging frames are wooden frames or tables set at an angle; their action is as follows: as the slime, which contains, say, a few pounds of tin to the ton, flows over the frame, the cassiterite, which is heavier than the mud, tends to settle on and adhere to the surface of the frame.

There is an attachment which works automatically, whereby a little counterbalanced tank fills with water, and when it is full it tips over and stops the flow of slime for a moment, while the richer tin slime which has adhered to the frame is washed off into a separate launder. These frames are used in large numbers, so that there is a continuous flow of slime going to them which, after it has passed over them is divided into two streams, one of slime tails which may be too poor for any further treatment, and a much smaller stream of enriched slime, which

would probably be further enriched by going over a second set. After the enriched slimes are good enough they are passed on to " round frames," or revolving tables ; here they are again divided into enriched slimes and tailings, the tailings are re-treated if they are worth it. Round frames are used in sets or banks of five or six or more ; the heads from these would flow over a second set, and the head from these would go into the tin yard for further concentration or roasting.

The Dressing Up of Concentrates.

The concentrates from tables, buddles, round frames, etc., are taken into the tin yard for cleaning up to the point when they are ready to send away. This is an enclosed building with a good floor, usually cement ; it must be well lighted for work by day and by night.

The tin concentrates, when received in the tin yard, are already classified into three or four sizes of grains. They consist of cassiterite mixed with particles of silica, tourmaline, and anything heavy which has been concentrated along with the tin. If pyritic matter is present in the original ore, it will be found in the concentrate and it will have to be roasted. This is generally done in a Brunton calciner, a circular furnace heated by a fire of anthracite. The ore is fed in above the centre of a revolving hearth and exposed to an oxidizing roast. The effect is that copper and iron pyrites are converted into sulphate and oxides ; arsenical pyrites are decomposed, the arsenic and sulphur being volatilized. The arsenic is recovered as grey arsenic from the arsenic chambers, and subsequently refined to " white arsenic," barrelled and sold. The sulphurous acid gas is scrubbed by passing through chambers through which water is kept trickling, and over wet limestone, as only traces are allowed to escape up the stack. The calcined ore, if it contained copper, is leached with water to remove copper sulphate, which is precipitated on scrap-iron.

If wolfram is present it will be necessary to pass this over a magnetic separator. If magnetic iron is present it is also necessary to use a separator. It is *possible* to dress a tin ore containing magnetite without a magnetic separator, but it involves such a great deal of labour that

it should never be attempted. When a mixture of cassiterite and wolfram is to be separated on a magnetic separator, it has been found (at any rate in some cases) that the separation is easier and more complete if the ore is warm.

If neither magnetite nor wolfram is present, the cooled ore from the calciners would be treated on shaking tables, as far as the crop tin and fine tin are concerned, and each class would then be further cleaned by tossing in a kieve. This may have to be repeated several times before the ore is fit for sale. Slime tin could not be treated on shaking tables ; it would be tossed repeatedly or treated first in a square buddle.

The degree of purity to which cassiterite should be dressed up depends mainly on the ease or difficulty of dressing it. With a clean ore and a light waste the dressing is quick and cheap, and there is very little loss in the operation. The large particles of cassiterite are very easy to clean and save, as they have no tendency to escape ; the finer particles can also be dressed with comparative ease, but the slimes are always a problem demanding the best skill and attention of the dresser. It is in such fine particles that it is very easily carried away in water, so that the dressing cannot be hurried, and consequently the dressing up of slimes is always expensive and loss must occur, because the whole of the cassiterite can never be separated from the " burnt leavings." It is in the final cleaning up that much of the loss occurs, so that it does not always pay to produce the highest grade of concentrate that *could* be produced, because it entails too much handling and cost of labour.

Underground ore can sometimes be dressed up to 70 per cent metallic tin, but where the ore is complex to begin with a final concentrate, containing 65 per cent, would be a satisfactory one if it did not contain more than 1 per cent of wolfram (as tungstic acid) and not more than 1 per cent of antimony, lead, bismuth, and copper taken together. The lowest grade that would usually be accepted by a smelter would be a concentrate containing 50 per cent tin (reckoned as metal).

After tin concentrates have been cleaned, the finished " black tin " is all mixed together, unless it is considered

advisable to sell it in two grades. Each grade is carefully mixed, and samples of about 8 oz. are placed in tins and submitted to buyers. The sale of tin concentrates is dealt with in Chapter X.

It is sometimes useful to know where to dispose of low-grade parcels, and sellers can obtain assistance by inquiring through a broker. There are firms who are prepared to purchase such parcels, but naturally they do not pay for the tin contained in them at the same proportionate rate as they would for cleaner concentrates. The losses of tin in the dressing of underground ores are not so heavy to-day as they must have been in past years, but in spite of the great care and skill that have been devoted to the question, they are still very high. In the past there was a tendency to undervalue the services of the tin dresser, but it is now better recognized that his duties are most important and ought to be properly rewarded.

CHAPTER VII

Alluvial tin : reasons why alluvial mining has assumed such great importance in recent years—List of the other minerals that may be found with cassiterite—The aim in prospecting for alluvial tin is to find large areas capable of cheap treatment—Cases where unfavourable conditions exist—Methods of testing—By pits, special warning as to precautions in testing ground by pits—Boring, precautions needed to ensure accurate results—Confirmation of pits and bores—Check boring—Verification of the character of the concentrates.

In the early days of tin mining shallow alluvial deposits supplied our needs, until the deposits then known became insufficient to meet the growing demand. Lode mining began to come into prominence about 400 years ago, and from that date up to about sixty years ago a great part of the tin supply was derived from lodes. The expense of underground mining, and its uncertainties, caused search to be made all over the world for alluvial tin, and to-day about four-fifths of the world's production is derived from alluvial deposits. The chief country to-day which produces large quantities of tin from lodes is Bolivia.

There are several reasons why alluvial tin mining has assumed so much importance. With the introduction of dredges, and of hydraulic plant, a few men can deal with very large quantities of alluvial ground at a very low cost per cubic yard. Although the raw material operated on may contain less than a pound of cassiterite per cubic yard, it often pays better than mining lodes containing twenty or thirty times as much. In alluvial mining a finished product is obtained with very little expenditure, because the mineral is free. There is a further very important point in favour of alluvial mining, namely, that it is possible to test a deposit and calculate the quantity of cassiterite that can be won from it. This is possible because an alluvial deposit is soft and shallow. After such a test it is easier to obtain finance for working it than it would be in the case of a lode deposit, which cannot be tested as quickly or as cheaply. Probably the most important reason of all is that practical experience of recent years has shown that large dividends can be paid

on alluvial mines, that have been well selected and carefully managed ; whereas there are comparatively few lode tin mines that have earned large profits in recent years.

Alluvial and detrital cassiterite are produced from the disintegration of lodes and stockworks, but probably the greater part has been derived from the weathering of stanniferous granite and contiguous rocks. The term " detrital," or " eluvial," is applied to deposits which are not strictly alluvial, as they have not been sorted or transported by water, but lie on or near their original site. To save repetition, both types of deposit will be mentioned under the general term " alluvial tin." In detrital deposits, where the mineral has not travelled far or been subjected to much rubbing, the characteristic crystalline form (see Chapter I) may be distinguished, and fragments of stony matter may be found adhering to the cassiterite.

In the case of water-worn alluvial, there may be very little sign of crystalline shape, and the mineral appears as a heavy gravel or sand, which may be black, brown, ruby, yellow, grey, or nearly white.

Sometimes these colours occur all together in the same concentrate. The tests for identifying it have been given in Chapter I.

As the specific gravity is between 6·8 and 7·2, it is easily separated by washing from earth and gravel, but it must be remembered that *any other heavy minerals present will be concentrated as well.*

Of these the commonest is magnetite ; others that are sometimes found are wolfram, ilmenite, rutile, chalybite, garnet, tantalite, zircon, monazite, and scheelite. The only two that have a gravity equal to that of cassiterite are wolfram and tantalite, the others can be panned away with care, but it is always essential to make certain that concentrates which appear to be cassiterite are really so, and unless the concentrates show on assay 70 per cent of metal some heavy impurity must be present. A description of, and tests for, the identification of the minerals mentioned above will be found in the Appendix.

In Chapter II is was pointed out that the aim in prospecting for alluvial tin was to find areas capable of being worked on a large scale.

Small or shallow deposits cannot be worked as cheaply as large deposits, and unless they are rich they may be useless. Alluvial ground may vary from a foot or so deep, up to 80 ft. or 100 ft. deep. A preliminary examination should be made, as described in Chapter II, to pick out areas worthy of detailed examination. Less than one pound of cassiterite per cubic yard will pay well in the case of large areas, where working conditions are favourable. A much higher figure would be required to pay profits in the case of small deposits. During testing it is important to watch for any difficulties, or obstacles, that might militate against the subsequent working of the ground.

The more complete the information that can be collected the less is the risk of ultimate failure. There are some cases where, although tin is present in fair quantity, there is little hope of working it at a profit. Such cases are these—

1. If there is no water near by and the cost of bringing on water would be prohibitive.
2. If the ground is covered with heavy timber or contains buried timber.
3. If there are serious difficulties in the disposal of the tailings.
4. If water is very limited and the ground is excessively clayey.
5. If the ground contains a boulder pack, or if the bottom is very hard and uneven.

Other conditions might exist where it is obvious that there are severe handicaps at the outset, so that it would be advisable, where possible, to make a preliminary examination of two or three areas and select that one which seems most suitable.

The area should be surveyed and a plan prepared, so that the position and result of each test can be entered on it.

The object of the tests is to ascertain the depth of the ground, its area, the amount of mineral that it carries, and the general physical state of the deposit.

Tests are made by either sinking pits or putting down bores ; in both cases the material brought up from them is washed to ascertain the quantity of cassiterite per cubic yard. Tests, whether by pits or bores, should be

made *systematically*, in a series of lines right across the area at measured distances. There must not be too great an interval between them. As a general rule, one pit or bore to the acre is a customary proportion. In testing alluvial ground each test must accurately represent the whole depth, from grass roots to " bottom." The bottom may be rock or clay ; the chief point is to make certain that the test reaches the bottom in every case, and that

Fig. 8. A Dredge at One of the Tronoh Tin Mines

the dirt brought up from a pit or bore represents the *real contents* of the ground tested, in precisely *similar proportion* as it occurs in the ground before it is touched. This would be a simple matter if the ground were dry, and if the cassiterite were evenly distributed in the dirt from top to bottom. As a rule, it is not evenly distributed, but is richest near the bottom. Close to the bottom there is usually a layer of sand and gravel (generally termed " wash "), and in this layer there is usually more mineral than there is in the dirt above it. It is, therefore, necessary to take great care not to get an undue proportion of this richer layer.

Pitting. To a beginner it might seem a simple matter to sample alluvial ground by pits, but those who have

had experience will agree that it requires great care, and even then errors may creep in.

It is useless to attempt pitting in marshy ground, for it is very unlikely that one would be able to reach bottom without baling or pumping, and these must be avoided. Even in ordinary ground, which is dry on the surface, pitting should only be attempted in the dry season, for if a pit bottoms in water it is very difficult to get correct results. As soon as the pit reaches the wash, which usually contains the richest material, water begins to trickle in, carrying in with it sand and mineral, so that one gets not only the mineral that one ought to get from the bottom of the pit, but additional mineral that enters the pit all round the sides. This is very marked if one tries the following experiment. Dig a pit which bottoms in water, and take out quickly all the dirt that seems proper to remove, and bale out the water; on taking more dirt from this pit a short time afterwards, possibly only a few minutes, it will be found that mineral has run in with the water from all round the sides to a surprising extent. When pits are dry from top to bottom the case is different, for the dirt taken out does accurately represent the values if one takes a proper proportion all the way down. It is not essential to wash the whole of the dirt from a pit if it is dry, so that one can take a measured "cut" from top to bottom down one side.

Such a cut can be taken, say, 3 in. by 4 in., so that a measured length represents a certain fraction of a cubic yard. On the other hand, if there is water available near by, it is a good plan to wash the whole of the dirt from pits in a small sluice box.

There is an advantage in pitting, as it enables one to see the bottom and whether there are any boulders or hard and creviced rock. In shallow ground, if dry, pitting may be preferred to boring, but for deep ground boring is quicker and cheaper. In wet ground pitting is not trustworthy, and boring must be employed.

Boring. The advantage of boring is that one can get accurate results, whether ground is wet or dry, and except for very shallow ground it is the cheapest. Boring is done by sinking into the ground, in a vertical position, a tube or casing from 4 in. to 6 in. in diameter, made in sections

that screw together. It will be readily understood that the friction to be overcome in forcing such a tube into the ground is considerable. There are two ways of doing this: either by having a weighted platform on the top of the tube and rotating the casing by long levers, or by jumping it down by repeated blows from a wooden rammer (the threads of the top end of the casing being protected by what is known as a " driving cap ").

It is impossible to force the tube down and pull it up full of earth as one can force a corer through an apple, for the friction is too great. Besides this, wet material would not be brought up. The dirt that enters at the bottom of the tube must be taken out frequently during the descent of the tube. This is done by using an auger-bit inside the tube (if the earth is dry enough to bring up in the auger), or a sand pump with a ball-valve if in the wet stratum. If stones are met with which prevent the descent of the tube, they can be crushed by jumping with a chisel-bit instead of the auger, but if the tube gets down on to a boulder which does not yield to several strokes of the chisel-bit, the hole must be abandoned, or the tube must be drawn up and a charge of explosive dropped down the hole.

The material taken out as the casing is put down is panned, and the concentrates weighed. This may be done separately for every 2 ft. or every 5 ft., or the concentrates from the full depth of the bore can be bulked together as desired. The depth of the bore is known by noting how many sections have been screwed on. It is of the utmost importance that the tube be kept *in advance* of the tools, or mineral may be drawn into the tube from outside. For example, on reaching the " wash " (water-logged sand and gravel), unless the tube is forced *tight* on to the bottom, one might pump sand and mineral considerably in excess of the correct proportions, and so get a result much above the truth.

In all cases close attention should be given to the following points—

1. Regular location of bore holes over the whole area being prospected.

2. Determination of a datum level for the whole area

being prospected, and the reduction of all bore holes to this level.

3. The carrying of all holes down to bedrock.

4. The keeping of drilling costs as low as possible.

5. The observance of the hard and fast rule that the tool which brings up the sample *never* projects beyond the cutting edge of the boring shoe.

6. The keeping of all parts of the boring equipment scrupulously clean.

Boring is an excellent method of examining ground if a proper number of bores are put down in proportion to the area. If either depths or values are found to be erratic, the proportion of holes should be increased. The rate of boring and the cost of boring vary considerably. In dry soft ground, free from large stones and buried timber, from 30 ft. to 40 ft. might be bored in a 10-hour day by ten boys and a white man, or by four white men and a horse. In bad ground, 15 ft. might be a good day's work.

In swampy ground, mud, or water, drilling operations may be started from a special scaffolding, or from boats or rafts, provided with a suitable length of guide tube through which the casing is lowered till it strikes ground.

It is seldom difficult to get the tube down, except in very deep bores, but drawing it again is often more difficult ; it may be drawn by a long lever attached to a collar or screw-cap, or by block and tackle.

The results obtained in boring are reported in pounds of " black tin " per cubic yard. The quantity of dirt brought up is calculated from the external diameter of the casing and the depth bored ; this can be checked by packing the dirt into a cubic foot box, and noting its volume, before it is panned down.

Confirmation of Pits and Bores. If the results obtained from pits or bores are favourable, it is desirable to confirm them by paddocks (or wide pits). The same warning is necessary as in the case of pits, that if a paddock bottoms in water there is a danger of additional mineral being carried into the paddock round the sides by water, so that the last stage should be completed with all speed, and no more pumping or baling should be done than is absolutely necessary. The advantages of paddocks are—

1. The nature of the ground is more clearly seen, so that one can judge better whether tree roots, clay or boulders, or uneven bottom is likely to give trouble.

2. One learns how much mineral is yielded by the ground on a larger scale as compared with the smaller tests from pits and bores.

3. A quantity of mineral is obtained, and its *commercial* value can be proved by cleaning it up and selling it.

4. By sluice-boxing the contents of paddocks we get an idea of the quantity of water required to separate the mineral.

These are all important points that will assist in forming a judgment as to the results obtainable on a working scale.

Check Boring. In wet, or deep, ground it may not be possible to confirm the results of bores by paddocks. In such cases it is customary to put down some additional bores to check and confirm those already made ; these check bores are usually made by another person. In check boring, besides reporting the depths and weights of concentrate obtained, the composition of the concentrates should also be assayed independently.

Verification of the Quality of Concentrates. When a large number of pannings and sluice-box tests are being made, it may not be possible to do fusions or chemical assays in every single case, but the concentrates may vary in quality in different parts of an area, so one must always be on the watch for variations. The concentrates from every panning, and a portion of that from every sluice-box test, should be crushed and vanned, and all the vans tested with the magnet and with acid. The vans should be bulked daily and a fusion or chemical test done *daily*. If it is found that the concentrates do not yield on assay 70 per cent or upwards of tin metal, they may require special treatment before they are saleable.

Wolfram can generally be removed from tin, so that no more than 1 per cent of tungstic acid remains in the cassiterite, but if they are inter-crystallized, it may not be possible to effect this by electro-magnetic separation alone. Scheelite is not often found with cassiterite, but when it does occur it has to be separated by chemical

means. Magnetite, ilmenite, wolfram, and monazite can all be lifted by an electro-magnetic separator.

As mentioned above, the sale of a quantity of mixed concentrates is a very good way of verifying the commercial value of the mineral obtained in testing an alluvial area.

CHAPTER VIII

Alluvial tin mining—The general values found in alluvial—Methods employed in working on a small scale—Calabashing—Ground sluicing—The advantage of water under a head—Monitors—Sluice boxes—Elevators or "blowers"—Gravel pumps—Dredging—Description of bucket dredges—Their capacity—The general conditions necessary to the satisfactory working of dredges—Suction dredges

The working of alluvial tin deposits is carried out in different ways, according to the nature of the deposit and the water available. Detrital tin deposits, where the material has not been transported by water but consists of decomposed rock on or near its original situation, are worked on similar lines. Detrital tin is sometimes attached to stony particles ; alluvial tin is generally free. To work either kind of deposit water is needed in quantity. If it can be obtained in abundance, and with a good natural head, very cheap working is possible. Again, where a deposit is suitable for dredging, costs may be very low.

The proportion of cassiterite is usually from under 1 lb. up to 2 lb. or 3 lb. per cubic yard, so that *large* quantities of dirt must be handled. In small deposits higher values may be found, but small deposits invariably cost more to work per cubic yard than large ones do. The chief obstacles to working alluvial (on large or small scales) are the presence of much stiff clay, and the intermittent character of water supplies. In many places it is a question of making the best of the water that is available, as there are few places where there is a full supply all the year round.

The gauging, conveyance, and conservation of water is dealt with in Chapter IX. The disposal of tailings requires attention, for everywhere there is greater strictness against covering up ground, or filling up water courses, than there was some years ago.

Just as there are lode deposits of tin which are too poor to work, so there are of alluvial. Also, there are deposits of alluvial which contain a fair quantity of mineral, but because there is not enough water, or for some other reason, it may be impossible to work them at a profit.

Small Scale Workings.

Where native labour is cheap and plentiful it often pays to collect cassiterite by the simple method of panning, or calabashing.

The calabash used in Nigeria is a bowl-shaped gourd. By swirling the dirt with water, the earth and sand are washed away, the pebbles are picked out, and the cassiterite is saved. There may be considerable loss of mineral if it is present in fine particles. The method of calabashing has the merit that there is no outlay for plant, and very little supervision is needed. The natives search for, find, and work a number of small scattered deposits that could not pay to work in any other way. They get small accumulations of mineral in the beds of streams, under boulders, and at the base of banks. They can wash the dirt they find in pools, or small trickles of water, which are insufficient for washing dirt in any other way. Tin winning can go on in this way during the dry season, when there is very little water available. Besides washing the pay-dirt that they can find on the surface, they frequently sink pits through poor overburden, and recover mineral from the pay-streak below. This is a wasteful method, as much of the tin is never got out at all, but it may be the best method to use in cases where water cannot be brought on by gravitation, and where it would not pay to pump it.

Ground Sluices.

Tin can be won without machinery by ground sluicing, if there is sufficient water and the ground is sloping. A ground sluice is simply a trench cut in the ground through which water is allowed to flow, so that the light waste is carried away and the cassiterite remains in the trench in a more or less concentrated condition.

Boulders are left where they lie or rolled to one side ; stones which can easily be moved are stacked up on ground that has been worked out. Ground sluicing should be started by digging a trench up hill, from the lowest part of the area to be worked, so that the tails flow away into a water course, if this is permissible. If it is necessary to impound them, the lowest part of the area should be worked out first, so that the tails are always flowing on

to worked-out ground, and it may be needful to build a rough wall to retain them as far as possible. When water is flowing along a ground sluice, even if the flow is rapid, it has but little effect on the sides, and it is generally necessary to break down the sides by manual labour. Unless there is a large stream of water, and the earth is very free from clay, ground sluicing may be a very slow process. On the other hand, if the water can be arranged to strike the side of the ground sluice, its cutting and disintegrating effect is at once felt. It is, of course, not advisable to enter upon an expensive scheme of bringing on water under a head, unless a sufficient body of ground has been tested and proved to justify the cost. At the same time, there are many places where it is worth using the water, even under a low head if the piping can be got cheaply enough. Where a large scheme is impossible, quite useful work can be done with ordinary 3 in. fire-hose, if a head of 50 ft. is available, using a $\frac{1}{2}$ in. jet. This will undercut the bank, and then the flow of water does the rest. The hose is also useful for washing out the concentrates from boulders which are too large to shift. A larger hose can be made by taking a roll of canvas and sewing the edges together and binding the end to a nozzle. This results in a low-pressure home-made monitor. For sloping ground there is no cheaper or quicker way of working than to strip it off with water under pressure, and hose can be taken where it would not pay to transport steel piping. There would be a great demand for a hose of 6 in. or 8 in. diameter, if it could be made to satisfy the following requirements: it should be strong enough to stand 25 lb. to 30 lb. pressure, light to transport, and not too expensive.

In ground sluicing the concentrate obtained is dug out from time to time, and cleaned up in small sluice boxes. It is generally necessary to sieve it into three or four sizes before the final washing. This is absolutely necessary, where the cassiterite is a mixture of crystals or lumps of very different sizes. The presence of stiff clay is a difficulty, as it rolls into balls and these balls pick up and carry away mineral. Where there is a choice of ground to work, that which is most clayey should be worked when there is most water.

The use of water under a head, even if it is a low head, helps to disintegrate the clay and reduce losses that might otherwise occur.

Monitors.

Monitors are employed for breaking down ground on a large scale, where it is possible to obtain a large quantity of water under a good natural fall. A monitor is similar to the nozzle used with fire-hose, but on a much larger scale. One can hold in the hand the nozzle connected to ordinary fire-hose delivering water under a pressure of, say, 30 lb., but where high falls are concerned the back pressure is too great. Monitors are supported on a heavy framework, and arranged so that the jet can be turned through a wide angle on each side, and elevated or depressed by one man. The size of the pipe line is proportioned to the volume of water, the jet may be from $\frac{1}{2}$ in. up to 3 in. or more. The pressure is, of course, dependent on the fall. With water under a natural head the cost of breaking down ground may be as low as 2d. or 3d. per cubic yard.

As a rule, monitors are employed where water is available under a natural fall, but they are also used where water has to be pumped.

They are an exceedingly effective means of working ground which is above the natural drainage level. They would probably be employed even more than they are at present if the cost of conveying water were not so great. Leat cutting in average ground is not particularly expensive, but where long pipe lines are needed the outlay for piping and its transport is costly, and for high falls strong piping is necessary. Spiral riveted piping is used for the sake of lightness, and is employed in sizes from 6 in. to 24 in. Heavier piping is made in curved sections like boiler plate.

Where wood of a suitable character is obtainable, pipe lines may be made much in the same way as barrels are put together, but using straight battens built up into tube shape, and tightened up by hoops and bolts. Such pipe lines can be made any length and to stand high pressures ; they are largely employed in the United States.

With a large and regular supply of water very cheap

working is possible, if the levels admit of the dirt flowing into sluice boxes without having to be elevated. In such cases the stream of muddy water carrying sand, gravel, and mineral is conducted into long sluice boxes. The light waste flows right through ; the mineral, stones, and some of the gravel settle in the sluice boxes. The larger stones are thrown out by means of stone forks. When it is judged that the sluice box requires cleaning up, the flow of water is checked, and the material in the sluice is worked up towards the head, and is then taken out and cleaned up in smaller boxes. It is generally necessary to sieve it into sizes before the final washing.

Large sluices are made of sawmill timber, with the bottom protected by spiking down lengths of tram rail, or they may be made of steel.

Elevators. It sometimes happens that it is necessary to elevate the dirt after it has been broken down from the face into sluice boxes.

If there is plenty of water available, under good natural pressure, this can be done very cheaply by the use of a " blower," or water-jet elevator. This is an upright tube placed vertically or at a slant, with its lower end dipping into a sump, the material to be elevated is washed into the sump. A small jet of water under high pressure is applied just inside the lower end of the blower, in the direction of the delivery end. When this jet is turned on it sucks up the pulp from the sump, stones, and all, and forces it up the tube and delivers it over a grizzly into a sluice box. Blowers do not pay in use unless water is obtainable under a natural head.

The proportion of dirt to water that can be lifted by them seems to be about 2 to 3 per cent, but it would probably depend on the velocity of the jet employed. Blowers are generally employed with a fairly high fall of water, but quite a low pressure will lift dirt, if the height it has to be raised is small and there are no large stones.

Gravel Pumps.

On ground that is not large enough or deep enough to employ a dredger, and where there is no natural fall of water to work a blower, gravel pumps are employed to

FIG. 9. A DREDGE AT THE TRONOH MINES

lift dirt into sluice boxes. A gravel pump is made on much the same lines as a centrifugal pump, such as is used for raising water. It consists of four essential parts: the helical casing or outer covering, the cover, through which the feed is drawn in, the shaft, and the runner or impeller. Gravel pumps are run off a belt from a steam engine, oil engine, or electric power derived from water or otherwise. They will pump a thicker liquid than can be delivered by a blower; that is, they will suck up and deliver a liquid containing some 5 or 6 per cent of solid matter.

They are ordinarily made to lift dirt up to a height of 30 ft. The same pump will throw it up a head three times as high with the expenditure of three times the power. They are made in various sizes, from 5 in. up to 16 in. The smallest mentioned requires about 16 h.p. to enable it to pump 30 ft.; a 16 in. pump would require about 100 h.p. The wear on gravel pumps is naturally considerable. The roughness and sharpness of the material, and the proportion of stones, naturally determine their length of life, but it is also dependent to some extent on the care and skill with which they are used. As an instance of a pump lasting a long time, one may quote a case in Nigeria where a gravel pump was used for three seasons (six months each year), working regularly nine hours a day. In this case a single renewal of the casing, cover, shaft, and impeller was needed. In other cases, if a pump were working day and night, it has been found necessary to make four replacements of each of these parts in twelve months. Like a blower, gravel pumps suck the dirt from a sump into which it has been washed by a monitor. A 5 in. pump will lift some 18 tons of dirt (solid) per hour, and a 16 in. pump will lift some 50 tons, to a height of from 30 ft. up to 100 ft.

For working ground, where it is necessary to lift the dirt into a sluice box, gravel pumps are admirable. They can be used either on a pontoon, or arranged so as to be easily movable from place to place as ground is worked out.

If the material that they are lifting is very hard and sharp, the cast-iron liners require frequent renewal. They are used either on a pontoon, so that they can be floated from place to place, or arranged so as to be movable as

ground is worked out. Like a blower, they suck from a sump, into which the dirt has been washed by a monitor.

Gravel pumps are made in sizes from 5 in. to 16 in., and have a capacity of from about 18 tons to 50 tons per hour for the sizes mentioned. They will deliver dirt up to a height of 100 ft.

The Working of Alluvial Below Natural Water Level.

Dredging. Where large areas are covered by alluvial, some portions such as the rivers, or low-lying flats, generally contain higher values than the ground above water level, and they may be undrainable except at great expense. In former times this would probably have been considered an insuperable obstacle to recovering mineral from them. To-day, such areas are specially sought for, because they can be worked very cheaply by dredging. Higher ground is also worked in the same way if sufficient water can be brought on to float the dredge and clean the mineral. Dredging has now been brought to such a point of efficiency that it is the cheapest method of winning mineral, with the possible exception of hydraulicing. A dredge represents a considerable first cost, but in a suitable situation and under good management a few men can handle a very large tonnage, and if not hindered by obstructions, lack of water, etc., it can continue to do this day after day with very few stoppages for repairs and replacements.

Dredges bring up the raw material, the values are extracted, and the tails are stacked continuously, and the whole plant being a self-contained and movable unit, works its way over the area as desired, so that there is no dismantling and re-erection of plant.

A dredge carries on its deck the necessary apparatus for washing, screening, and collecting the values. With alluvial tin the particles are generally free, and are not excessively minute like the slime tin, which gives so much trouble in the dressing of underground ore. If it were, it could not possibly be saved in the limited space on a dredge, but the tin being for the most part in comparatively large particles, the recovery is generally very good.

The bucket dredges employed in tin winning are very

similar to those used in keeping channels open for navigation. They dig up the bottom by means of an endless chain of buckets. In the older type of dredges the buckets were spaced out on the chains (open connected), but now they are placed close together. The number of buckets naturally depends on the depth to be dredged, and their size varies considerably—a very small dredge having buckets of, say, 1 cub. ft. or 2 cub. ft. capacity, while a large dredge may have buckets of, say, 7 cub. ft. to 12 cub. ft. capacity, or even larger. The capacity of modern dredges varies from 10,000 cub. yd. to 40,000 cub. yd. per month (actual raising capacity) for a small dredge ; up to 100,000 cub. yd. to 200,000 cub. yd. per month for a large dredge.

It is possible to raise, or lower, the jib so that the buckets are digging up dirt at a depth of only a few feet, or at a depth of over 80 ft. below the surface of the water on which the dredge is floating.

As the dirt is brought up it passes through trommels, where it is washed by water under pressure to disintegrate it and to take out large stones. The tailings may carry monazite or zircon.

The general conditions suitable for the profitable exploitation of alluvial by dredging are as follows—

1. The area of the ground must be large and must have been proved by careful boring to contain recoverable mineral worth on the average, say, not less than 9d. per cubic yard in temperate climates, and a higher value in climates where any cause prevents work from being carried on regularly all the year round.

2. The ground should be free from buried timber, large boulders, or *much stiff clay* ; clay causes loss by balling —the clay balls carry away tin.

3. There must be sufficient water to float the dredge and to clean the mineral at all times.

4. The bottom should be *soft* rock ; very hard or creviced rock is not suitable, because unless the upper soft layer of rock can be cut away, and brought up in the dredge buckets, a quantity of mineral may be lost in crevices or pockets. The bottom should be reasonably level, if there are pinnacles of rock they may be a serious obstruction.

5. The area in which the dredge is to work should not be exposed to violent storms or floods, or if it is, provision must be made to protect the dredge from being carried away.

6. The place to which the parts of the dredge will have to be taken to be assembled must be accessible ; if everything has to be brought along bush paths or over rough country, the transport may be very expensive.

7. The cost of power must not be excessive unless the deposit is rich enough to stand high costs. In some places coal is not obtainable, and the supplies of wood suitable for fuel may be scanty. Dredges have usually been operated by steam, but they are now also worked by oil engines, by suction gas, and by electric power generated from water.

Suction Dredges.

These are a much later introduction than bucket dredges. The bucket dredge was first used in New Zealand (for winning gold) about the year 1888. The earliest types were not always successful for various reasons. In the same way we should expect that suction dredges under some conditions would not give satisfactory results, and they have not yet been in use long enough to bring them to the same state of efficiency which has been attained by bucket dredges. Suction dredges were introduced about twelve or thirteen years ago ; some are in use and more are in course of construction, so that before long considerable experience in using them will be gained.

Their first cost is much less than that of a bucket dredge of equal raising capacity. They dig the dirt by means of a revolving cutter, which is pressed against the ground under water. The dirt falls into an opening connected to a gravel pump, which sucks it up and delivers it into similar apparatus (trommels, etc.) as are used on bucket dredges. In soft easy ground, suction dredges have been found very satisfactory, but stiff clay appears to make their use inadvisable.

CHAPTER IX

Power for mining purposes—Water-power, the seasonal character of most water supplies—Gauging of water—Power obtainable—Water wheels—Screens and grids—Turbines—Pelton wheels—The storage and regulation of water—Temporary and permanent dams—Conveyance of water—Pipe lines and rate of flow—Steam-power—Care of engines and boilers—Suction gas engines—Distribution of power.

THE cost of power is always an important item, and in considering which class of power to use we have to take into account local conditions, the prime cost of plant, the running cost, depreciation, and whether there is any difficulty in ensuring its regularity.

1. *Water-Power.* In a few countries the streams and rivers are large and practically constant all the year round; in most countries the available water supplies are very seasonal in their character.

For instance, in a water course in the Tropics, during the rainy season, there might be such a quantity of water coming down that it would seem an attractive source of power, but when the rainy season was over, there might not be enough water to fill a kettle. In semi-tropical countries, also, there are streams which furnish very useful power in the wet season, but do not run at all in the dry season. In countries which are inhabited, it is usually possible to find out by inquiry whether a particular stream, or river, is permanent all the year round, and the limits of its rise and fall. Where no such information can be obtained, the traces of the last flood level can sometimes be observed from the dried rubbish caught up in the scrub growing on the banks, but there is no equally easy way of ascertaining how low the water will be in the dry season, except that one may form some idea by examining the erosion of the banks, and the height above the bed where the vegetation begins to take root. The variability of water supplies is one reason why they are not made more use of; the other reason is the cost of harnessing them. If the contour of the country is favourable, it is often possible to turn variable supplies to good account, but large expenditure should not be entered on

without most careful inquiry into the average rainfall, and the period over which it is normally spread. While caution is essential before spending money in harnessing water, where the conditions are favourable water-power should never be neglected.

A low-grade mine, with water-power, might easily be more profitable than a richer one where all the power has to be generated in some other way. Much tin has been won in the past which could not have been got at all except for the assistance of water-power, and there are no mines where one can afford to neglect any means of keeping down his power costs. In many mines there is but little scope for obtaining power from water. This is more particularly the case in closely settled countries, where the mining area is circumscribed, and where the natural water courses are small or already utilized.

We see in Cornwall, and also places abroad, how careful the older workers were to bring water, even when they had to do so from long distances. The fact that to-day we have means of producing power in ways that were not available in their time, should not cause us to neglect natural power wherever we can use it to advantage.

Measurement of Water-Power. Power is obtained from water by causing it to do work as it is flowing from one level to a lower one. The quantity of power obtained depends on—

(1) The height the water falls.
(2) The quantity of water which is falling.
(3) The type of water motor employed.

There are different forms of water motors, and choice of which to employ is determined by the height of the fall. Before describing them it will be convenient to give the methods of gauging flows of water, and calculating the power they will yield.

The unit of power (or mode of reckoning power in this country) is the " horse-power " ; this is the power required to raise 1 lb. 33,000 ft. (or 33,000 lb. 1 ft.) in one minute. From this formula we see that 33,000 lb. of water, falling through 1 ft., would produce 1 h.p. if we could obtain the whole of the power. In actual practice some of the power is lost, however well designed the water motor may

be. The efficiency of each machine is given under its description.

The flow of water can be measured, in the case of a small stream, by the "Sill" method. A section of the stream is chosen where it is convenient to set a board in the channel, at right angles to the flow, and make all the water flow over it. The board must be straight-edged and set perfectly level and planed, so that it is brought to a knife-edge, where the water flows over it.

The board should be a definite number of feet long, and should be nailed to two uprights, and backed with turf so that no water escapes underneath or at the sides, but that all the water passes over the sill between the uprights. Under these conditions we are getting a flow so many feet wide and so many inches deep. The quantity of water is gauged by measuring the depth of the water passing over the sill and the length of the sill.

The best way to measure the exact depth of the water passing over the sill is, not to place a rule in the water on the top of the sill as the water is beginning to curve over as it descends, but to measure from the top of a stake, which has been fixed 6 ft. higher up the stream, with its top exactly the same height as the sill. Now, supposing that the sill is, for example, 6 ft. wide, and the water flowing over it is 4 in. deep, we can learn how much water is passing over it from the following table—

Depth over sill 1 ft. wide	Cu. ft. per min.
1 in.	4·7
2 ,,	13·5
3 ,,	24·8
4 ,,	38·2
5 ,,	53·4
6 ,,	69·4

so that from the example above, a flow of 4 in. over 1 ft. of sill would be 38·2 cub. ft., and as the sill is 6 ft. wide, the flow is equal to 229·2 cub. ft. per minute.

One cubic foot of water is equal to 6·2 gals., so the flow in this case is 1,421 gals., or 14,210 lb. of water by weight. Suppose that there is an available fall of 22 ft., so that

the water can be used to turn a 20 ft. overshot water wheel (a 2 ft. loss must be allowed to get the water away again from under the wheel in the tailrace), the weight of water going over the wheel per minute, multiplied by the height it falls, and divided by 33,000, will give the theoretical horse-power obtainable ; 14,210 multiplied by 20 and divided by 33,000 is 8·5, but as an overshot wheel has only an actual efficiency of 65 per cent, the true horse-power will be 5·5.

In cases where a large stream or a river has to be gauged, it would be difficult to make a sill large enough to take the whole flow. The method to use in such a case is to choose a part of the river where the banks are nearly vertical, and to take several measurements of the depth and width, so as to get an average. Multiplying these together we get the area of the flow. The next thing is to find out the rate of flow. This is done by throwing into the stream a bottle, or piece of wood, and noting with a watch how far it travels in one minute. This should be done several times, and the average distance in feet recorded. To ascertain the *mean velocity*, observations taken in the centre should be reduced by multiplying them by ·83 ; this allows for the retardation of the water due to the friction of the banks and the bottom. The area of the flow multiplied by the rate gives the number of cubic feet passing per minute. The fall is estimated by a staff and level. Even if it is a small fall, if the volume is large it can be made use of.

Water Wheels. These are built in three forms ; the ordinary water wheel, or overshot wheel, has a number of buckets which are filled as they are at the highest point. These wheels are built of steel or wood. The usual construction is a cast-iron axle, wooden arms, a cast-iron ring, and wooden buckets and backing boards. Such wheels are made for falls of as little as 6 ft. and up to 40 ft. Sometimes they are built larger than this, but even a 40 ft. wheel is difficult to keep in order, and for falls higher than 40 ft. a turbine would be more suitable.

The efficiency of a well-built water wheel, in perfect order, is as much as 65 per cent, but they are very seldom given the attention required to maintain this efficiency.

The breast wheel is similar to an overshot wheel, except

that the water is not applied to the top, but part way down. Its efficiency is 55 per cent if in perfect order.

Where there is very little fall, so that the water cannot be made to flow over a wheel, the undershot wheel is used. This wheel has floats or flat boards, instead of buckets, and is set over the stream in such a way that the floats are submerged. They were much used many years ago, but their efficiency is very small, being only 35 per cent.

Overshot wheels are still used a good deal in mining. They are slow-moving machines ; their rotation in the case of medium-sized wheels is from about 10 to 15 revolutions per minute. Gearing is often required to connect them up to the machinery they are intended to work, and as water wheels are generally " quarter heavy," the gearing must be strong. Quarter heaviness does not occur in all-metal wheels.

In wooden wheels, it is due to the fact that one part of the wheel becomes drier than the rest of the circumference, and when the wheel is stopped it comes to rest with the lightest part at the top. This causes the wheel to deliver its power unevenly, and the wheel is liable to run backwards when it is stopped. To avoid breakage of the machinery, it is usually connected (with a stamp axle, for example) by a ratchet and pawl, so that if the wheel does run backwards it does not reverse any machinery it is connected to. If it is desired to gear up a water wheel to give sufficient speed to run a saw, shaking table, or compressor, it would be best to use a rope drive. Belts do not give satisfactory results, owing to the slow speed of water wheels, and cog wheels are very liable to be broken. Water wheels, like all other moving machinery, must be securely fenced in to avoid accidents. During repairs they must be trigged up, so that they cannot move in either direction. To get good service from water wheels the following precautions must be taken—

1. They should be covered to prevent the sun from drying the upper portion, and to prevent ice from forming on the wheel in winter.

2. The segments are apt to work loose, so the bolts should be gone over every week.

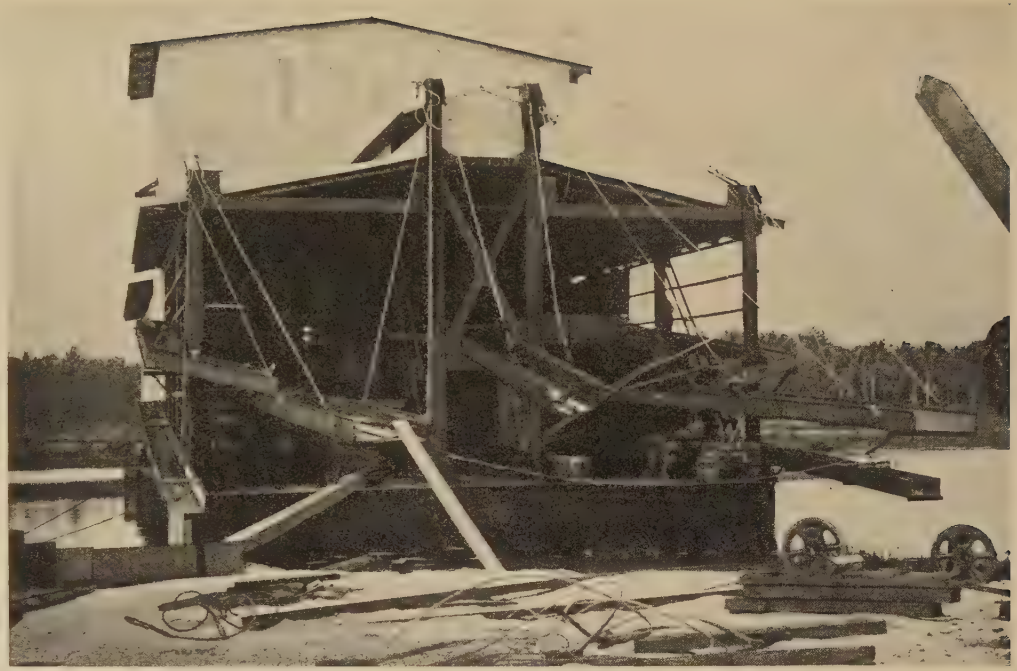

FIG. 10. STERN VIEW OF A DREDGE SHOWING THE CHUTES FROM THE JIGS
(Malayan Tin Dredging, Ltd.)

3. The buckets and backing boards must be kept tight, so that there is no loss of power through leaks.

4. The arms require special attention ; if they show the least signs of play the wheel must be stopped until they are tightened up.

5. The bearings must be covered in to exclude grit and water, and they should be lubricated with a good grease, not a thick tar mixture.

Water wheels will continue to give *some* service even if neglected, and this often leads to their being allowed to get into such a state that their efficiency is probably nearer 30 per cent than the 65 per cent that they are capable of when in proper condition.

Screens or Grids.

There is no particular need to screen out leaves or weeds or small sticks from water that is going over a water wheel, though it is wise to have a coarse screen ; in the case of water which is going to be used to feed a turbine or a pelton wheel, a close screen should be used. This is best made of iron bars set 1 in. apart ; it should be large and set on a slant, as then it does not require such constant clearing.

If there is much floating rubbish in the water, screens may need clearing two or three times a shift.

Turbines.

Turbines are constructed which will work efficiently with very low falls of water. As low a fall as 12 in. of water can be utilized, and patterns are made to work with falls up to 400 ft. or 500 ft.

They work by the rotation of a spindle to which vanes are attached, which are caused to move by the flow of water in its rush from the upper to the lower level ; the power depends on the quantity of the water available, and the height through which it falls, and to some extent on their design. Their efficiency may be as high as 75 to 85 per cent. Turbines are made in a variety of sizes, suitable to work with quite small quantities of water, up to sizes taking very large flows, far greater than could be dealt with on water wheels. In recent years their construction has been greatly improved, so that now they can

be obtained to yield a high efficiency combined with strength and simplicity. They may be regarded as a greatly improved form of water wheel and, as they give a considerably higher speed, they do not require gearing up as would be needed for many purposes, in the case of a slow-moving machine like a water wheel. The speed of turbines may be made (according to the type of construction) to be as low as 50 revolutions up to 400 revolutions per minute.

Pelton Wheels.

These machines are not suitable for low falls, but for any fall not less than 70 ft., and up to any height they are excellent. Like turbines, they depend on the impulse they receive from the velocity and volume of the water that is fed to them. Their efficiency depends on the correctness of their design, and may be from 80 up to 90 per cent. They are a very high-speed type of machine compared with water wheels, and differ from them thus: in a water wheel the water flows into buckets and descends slowly as the wheel turns, and falls out as the bucket becomes inverted in its rotation.

In the pelton wheel, the water is supplied from a pipe through which the water flows with considerable velocity, and the water, instead of filling a series of slow-moving buckets, strikes with violence against a series of double cups, bolted on to the periphery of the wheel, causing it to rotate rapidly. The jet strikes the centre of each pair of cups, which are so placed that as soon as each one receives the jet the water flies out on each side, after having transmitted its energy to the wheel.

To avoid splashing, it is customary to have the pelton wheel encased by a covering of metal. The water is usually applied to the pelton wheel through one jet or nozzle, but two or more jets can be used on the same wheel. The wheel is usually termed the "runner," and the small buckets against which the water strikes are called "cups." The speed of the wheel depends on two factors: (1) the higher the fall the greater the speed, and (2) the larger the diameter of the wheel the slower the speed.

It is possible to vary the speed of the pelton within considerable limits for a given fall. For instance, if a fall

of 250 ft. of water is used on a pelton wheel 2 ft. in diameter, the speed would be about 550 revolutions per minute, but if the diameter is 6 ft., the speed would be about 190 revolutions per minute, the power in each case being the same. It is possible to mount two or more runners of different diameters on one shaft, and to apply water-jets fed from different levels.

Storage and Regulation of Water.

As water supplies are almost always liable to considerable variations, according to the season of the year and the rainfall, it is often useful to have means of regulating and storing water, in order to conserve it when it is not required at night, or during week-ends, and to take advantage of heavy showers, and to tide over temporary droughts.

In cases where natural lakes can be tapped, very large natural storage is obtainable. In other cases, it may be possible to make a pond by building a dam. When a dam is necessary, it is of the utmost importance to build the retaining wall in such a manner that it can neither be swept away by extra pressure due to a heavy flood, nor undermined and cut through by leaks in or under the retaining wall.

The retaining wall must be carried down into firm clay or rock. For a deep dam it is useless to make a wall in sand and gravel, unless it can be carried down to firm and impervious material. In the case of shallow dams, it may not be necessary to build a masonry or concrete wall, and the expense in some countries would be prohibitive.

A wide earth bank, if the earth contains some clay and is well beaten down and properly sloped, can be employed in most cases instead of masonry or concrete. In all cases it is essential to provide normal and storm overflows, not only abroad, but at home. The side of the dam down which the water runs from the overflow must be close-boarded, or paved, with stone set in cement. Besides the overflow on the dam itself, a by-wash should be made wherever needed on the water course that feeds it. The great object to be observed in the construction of earthwork embankments is to prevent percolation of the water through the mass of the work, or underneath

it. If this is neglected the collapse of the wall may take place at any time. The forces which oppose failure of the wall are its weight and its frictional resistance to sliding. Should water saturate the wall or any stratum of it, two destructive forces come into action: a horizontal force tending to make the wall slide, and an upward force tending to lift the material. The lifting action is due to the depth of water above the porous stratum. Therefore the core of the dam must be made impervious and solid, so as to allow no water whatever to pass through.

The site for a dam must be carefully examined. Solid rock is the best foundation, but this is not always obtainable, and a layer of clay of sufficient thickness to prevent the percolation of water, will satisfy. Tree stumps should be removed, for if the dam is intended to be a permanent one, after the stumps have decayed water may find its way through the cavities that are left. A puddle wall is usually placed in the centre of the dam. Some engineers advocate puddling the inner sloping wall, so as to prevent the water getting into the wall itself. But as all earth banks sink about 2 in. in the foot after construction, there is a risk of a crack forming in the puddle wall and letting the water through. The subsidence of the general mass of the dam tends to consolidate the puddle wall placed in the centre. The puddle wall is let into the foundation by a trench.

This is filled with tenacious clay, or clay and turf, and well rammed down. The clay must be soft so that it can be easily rammed into a coherent mass. The trench being filled, the embankment and the puddle wall are carried on simultaneously. The delivery pipe should not pass through the embankment wall, as it is difficult to prevent water finding its way along the outside of the pipe line, thus endangering the dam. It should be laid in a trench below the dam, and well rammed with clay before the dam is built over it. A cage strainer must be placed over the mouth of this pipe. A suitable valve must be provided to turn on and shut off the water.

Conveyance of Water.

Where water has to be conveyed for a distance, it is generally possible to contour an open leat so as to avoid

fluming and tunnelling or the use of pipes, until the water has been brought close to its final destination.

A leat can be made in any kind of soil, even in sand or gravel. There may be some loss of water in soakage at the start, but this can soon be stopped by stirring up mud, or clay, in the water before it arrives at the porous section. It will settle and soon close up the pores in the ground. In sandy or gravelly ground the sides of the leat should be lined with turf, or built up with stones. When crossing gullies it may be necessary to use some fluming, or on the side of a rocky bank. Large boulders should be left where they lie, and the leat contoured round them. The best fall for an earth leat is about 6 ft. in the mile.

Water will travel in a boarded leat with a fall of as little as 4 ft. in the mile. In an earth leat a fall of over 8 ft. will cause the water to run fast enough to scour it too much, while if the fall is under 6 ft., mud will settle. Sharp corners should be avoided, and a good batter should be left on the sides if they are not lined with stones. A leat 6 ft. wide at the bottom and 2 ft. deep will carry over 1,000 cub. ft. of water per minute with a fall of about 6 ft. in the mile. Theoretically, it would carry more water than this, but in practical use stones fall in, the banks get stamped in by animals, gravel collects, water weeds and rushes obstruct the flow, so that one should not expect more than 1,000 cub. ft. per minute.

Leats require attention from time to time ; by running out nearly all, but not quite all the water, one can see where the bottom has become silted up, and throw out the dirt where it is really necessary ; gravel has to be shovelled out, and loose mud can be washed out by cutting through the bank at suitable places.

Regulation of Water in Leats. In a long leat with good banks the water can be ponded to a certain extent. By placing hatches at intervals water may be saved that would otherwise be wasted at night or during week-ends. There may also be places along a leat where storage ponds can be made with very little expense.

Pipe Lines. In some cases it is necessary to convey water in pipes, as in crossing valleys or to obtain a head when it is going to be used under pressure, as in a pelton wheel, turbine, or a monitor.

When water flows through pipes there is a loss of head, owing to the friction of the particles of water with the sides of the pipe. This friction increases with the length of the pipe and the velocity of the flow. The larger the pipe the less is this loss through friction, so that in bringing water to feed any form of water motor, the pipe should not be less than a certain size. The cost of wide pipes leads sometimes to the use of pipes that are not so large as they ought to be to convey the water, and so power is lost. *The relative capacity of pipes varies as the square of the diameter.*

Most makers of water-power plant agree that the flow through a pipe should not exceed 8 ft. per second. As an example, a pipe of 6 in. diameter, 1,000 ft. long, with a total vertical fall of 100 ft., which is used for supplying water to a pelton wheel, would show a pressure at the bottom of 43 lb. per square inch if the water is *not* flowing, but if 100 cub. ft. are flowing per minute the pressure is reduced to 33·5 lb.

In this case the 6 in. pipe is too small to convey the water without considerable loss of power; with a 9 in. pipe the loss would be much reduced.

Material Used for Pipes. Small pipes are made of wrought-iron, steel, or cast-iron. Large pipes are made from steel, riveted in spirals, or curved plates. There are various methods of jointing. Abroad, where wood is obtainable very cheaply in large quantities, large pipe lines have been built up of long staves, arranged to form a tube like an elongated cylindrical barrel, bound with steel bands.

The heavy cost of pipe lines is one of the chief reasons why water power is not more generally employed. As an indication, the following flows *should not be exceeded* through the size of pipe mentioned—

In a	3″	pipe	30	cub. ft.	per min.
,,	4″	,,	40	,,	,,
,,	6″	,,	70	,,	,,
,,	7″	,,	96	,,	,,
,,	8″	,,	125	,,	,,
,,	9″	,,	160	,,	,,
,,	10″	,,	195	,,	,,
,,	12″	,,	280	,,	,,
,,	18″	,,	630	,,	,,
,,	24″	,,	1,130	,,	,,
,,	30″	,,	1,760	,,	,,
,,	36″	,,	2,500	,,	,,

In practice, however, one has to consider the heavy cost of large pipes, and as water increases in velocity as it flows down a pipe, one can decrease the diameter of a pipe line slightly for the latter part of the fall.

Steam-Power. This is at present the power most frequently employed in mining, for the reason that a steam engine can be started and stopped at once, as in hoisting, and provides a much greater degree of ranges of power than is obtainable with oil engines or suction gas engines, which are most economical when run at their full load. Steam engines have been brought to a great pitch of efficiency in recent years, and both engines and boilers can be obtained sectionalized for transport over difficult country. One great advantage which steam possesses, in addition to its flexibility, is its certainty, and the fact that less skill (though not less care) is required to drive and maintain steam engines in good order than is the case with internal combustion engines.

There are two or three main points that must be considered when it is proposed to employ steam engines in working a mineral deposit at home or abroad—

1. A steam engine requires a considerable quantity of water, and some waters have a bad effect on the tubes and plates, so the character of the feed water should be looked into ; if it is too soft, or too hard, or acid, the proper corrections must be applied to make it fit for use in boilers.

2. If wood is to be used as fuel, the fire boxes must be designed for this fuel, and wood varies very much in its steam-raising efficiency.

Some soft woods, such as the cotton trees of the West Coast of Africa, are almost useless as a fuel, and even hard wood gives poor results unless dry and sound. In the Tropics wood perishes quickly and loses its quality, unless it is brought under cover.

3. The cost of felling and collecting cord wood for a boiler often works out at a heavier figure than one would expect, and the cost increases as nearby supplies are exhausted.

Care of Steam Boilers and Machinery. Steam boilers should always be lagged to prevent waste of heat ; this is often neglected in small plants and great waste of fuel

results, and the plates are exposed to objectionable stresses. In blowing out dirty water from a boiler, the pressure should not exceed 5 lb., and the fire should be entirely drawn beforehand. When native firemen are employed, care must be taken to see that they are regular in firing and in oiling up all bearings, and that they do not admit cold air into the boiler more than is absolutely essential in firing, and that they understand the use of the water gauge and pressure gauge. In tropical countries, machinery and boilers that are not in use deteriorate very quickly. If machinery is carefully tallowed and attended to it can be kept in order, but it is more difficult to avoid injury to boilers. The best plan is to keep them full of water and to raise steam, say, once a month, and run the engine for a short time. Every time a steam engine is started some of the steam condenses in the steam pipes and the cylinders, and care must be taken to open the drainage cocks. In small amount water produces "knocking," and if the cocks are opened in time injury may be avoided, but it should be a routine procedure to open them always before steam is turned on. Also, steam should always be admitted gradually. If it is turned on too quickly it is a cause of leaky joints. All glands should be repacked if any escape of steam is seen, and if a single thickness of gland packing is used, it should be cut diagonally to make the joint tight.

Where a condenser is used with steam engines, 25 gals. of cooling water are needed to condense the steam evaporated from 1 gal. of water. Where wood is used for fuel, the fire-grate and heating surface should be large in proportion to the horse-power capacity of the boiler.

Oil Engines. The oil engine is a development of the gas engine. A few years ago, all oil engines were worked on petrol or paraffin, but the most modern and economical types now use heavy oil. The consumption of oil varies with the size, but is about half a pint to three-quarters of a pint per horse-power hour.

The Diesel engine (if of the four-cycle type), works as follows: The suction stroke draws air into the cylinder without fuel. The compression stroke compresses this air to about 500 lb. per square inch. On the commencement of the third stroke, a fine spray of oil is injected for

a small part of the stroke, at a pressure of about 700 lb. The air is highly heated by the compression of the second stroke, and the injected oil is thereby fired, the gases produced expanding. The fourth stroke is the exhaust, and the spent gases are swept out of the cylinder. The following points are to be noted.

There is no ignition apparatus, as the heat of compression of the air fires the mixture. The great advantage of Diesel engines is that they can be run on crude, cheap oils. They are made in a variety of sizes, from as small as 6 h.p. up to 2,000 h.p. per unit. A small engine, say, up to 20 h.p., can be started by swinging the flywheel by hand at half compression ; larger ones are started by a compressed air bottle. Less constant attention is required to run an oil engine than a gas engine, as the strength of the explosion is not dependent on skill in stoking, as it is in the case of a suction gas engine. The heavy weight of the flywheels and cylinders of oil engines makes them more difficult to transport to places where access is bad, compared with steam engines and boilers that can be sectionalized.

Suction Gas Engines. Suction gas can be made from anthracite, peat, charcoal, wood, or many kinds of vegetable waste. Suction gas engines are made in a variety of sizes, from 10 h.p. up to 2,000 h.p., the latter having several cylinders. In certain cases suction gas may be the cheapest power to use, because gas can be generated that will work them satisfactorily from materials that would not be fit to raise steam with. There are places where it would be very expensive to get supplies of heavy oil, coal, or anthracite, where some material can be got cheaply that will yield a combustible gas. When anthracite is used to generate the gas, the weight of anthracite used is something under $\frac{3}{4}$ lb. per horse-power-hour. It would be rather more if the plant is not running continuously. Where wood, peat, or vegetable waste is used to generate the gas, special care must be taken to scrub the gas free from acids, or corrosion will occur in pipes and cylinders.

In a suction gas plant the gas is produced by the action of air and water vapour on the hot carbon in the generator, which is kept at such a temperature that the water vapour

is decomposed into carbon monoxide and hydrogen. The flow of gas from the generator is produced by the piston sucking the gas, as fast as it is formed in the generator, through the scrubber, tar extractor, and water seal.

When the gas enters the cylinder it has already been mixed with a sufficient amount of air to form an explosive mixture. At the next stroke it is compressed, on the third stroke it is fired (the power stroke), on the fourth stroke the products of the explosion, having done their work, are discharged from the cylinder, and a fresh charge of explosive mixture is drawn in and the cycle repeated.

In buying a second-hand plant, or ordering a new one, consideration must be given to the kind of fuel that is going to be used, for the generator made to run a given engine on anthracite would be much too small if later on it were desired to use a more bulky material. It requires some experience to get and maintain a good gas mixture.

If the plant is run during the day only, and shut down at night, there should be good gas in the morning in the apparatus to restart with. The fire in the generator can be kept alive by allowing a little air to pass through, so that all it needs in the morning is a few minutes' blowing up. In starting from "all cold," kindling is laid in the generator with the fuel and lighted. There is a rotary blower worked by hand to blow up the fire. While the fire is getting up the waste gases escape at the top of the generator. When the fire is hot, and the operator wishes to see if the quality of the gas is good enough to start with, there are test cocks where he can light the gas and see if it burns properly. If not, he must go on blowing up the fire till he gets a gas that burns well. Then he stops blowing, adjusts the valves so that gas can pass from the generator to the cylinder, and starts the engine. The start is given from a compressed air bottle. It is probably due to the great popularity of heavy oil engines that suction gas engines are not more used at present, but there is no question that they have great merits, particularly where the work is continuous and the load regular.

Wind-Power. This has seldom been applied to mining, partly on account of its uncertainty, but chiefly because

it has not yet been found possible to make a unit that will yield any power beyond 30 h.p. to 40 h.p. There are two general patterns—

1. The circular type used for pumping water, which is made in sizes from 8 ft. to 20 ft. in diameter. They can only operate very small pumps, as the largest only produces about 1 h.p.

2. The old-fashioned windmill, with four sails, exposes a surface of some 576 sq. ft., each sail being 24 ft. long. The speed in a good wind is up to 22 revolutions per minute, and the power would be not much more than 5 h.p.

Distribution of Power.

Any of the methods mentioned above for obtaining power can be used to generate electrical power, and this can be conveyed for short or long distances. A further advantage is that it can be divided up, so as to actuate a number of machines which can be started or stopped at once by the turning of a switch.

The advantage of this can be well seen when it is desired to bring power from a distance ; for example, there may be a useful source of power to be obtained from a fall of water some miles from a mineral deposit. Years ago it would have been impossible to use this power unless the water could be contoured, so as to bring it close to the deposit. To-day, the power station can be placed at the most convenient spot, and electrical energy can be conveyed for miles with very little loss of power. The cost of the conducting wires, posts and insulators, on which the wires are carried, is comparatively trifling compared with the economy effected by use of the water. In the same way electrical power, produced from steam engines, may be purchased from power companies whose mains pass a mine, and such power, being produced on a large scale, is usually sold at a rate that pays the mine to buy part, or all, of the power they need rather than generate it themselves.

CHAPTER X

1. *The production of tin in different countries*—2. *The sale of tin concentrates*—3. *The smelting of tin concentrates*—4. *The uses of tin*—5. *The recovery of tin from scrap, "Secondary tin"*—6. *The present and future price of tin.*

TIN is the rarest of the so-called base metals; it occurs in certain fairly well-known districts in a few countries, but it is not nearly so widely distributed as copper, lead, or zinc.

There are now three countries which provide the main bulk of the world's supply. These are the Dutch East Indies, the Malay Peninsula, and the South American State of Bolivia. There are a number of smaller producers, namely, Australia, Burma, Nigeria, China, Siam, Mexico, Swaziland, the Transvaal, Spain, Portugal, and the United Kingdom. Besides these, there are one or two others about which less is known, namely, the Belgian Congo and the ex-German territory of South-West Africa. The three large producers mentioned first furnish over 30,000 tons a year each; the production from all the others is comparatively small. There is reason to expect an increased production from all countries while the price continues high. The total world's production is steadily increasing; it now amounts to about 140,000 tons a year, calculated as metallic tin.

1. **Tin Production by Countries.** (These are arranged in alphabetical order for convenience.)

Alaska. A few tons of tin have been produced in Alaska during the past ten years, amounting in all to some 500 tons, but for the last few years it has dropped to two or three tons a year.

Australia. The production, excluding Tasmania, was for several years about 5,000 tons yearly. Some four years ago it dropped to under 3,000 tons a year. The greater part comes from New South Wales and Queensland. It is derived partly from lodes but mainly from alluvial.

Bolivia. The tin is derived almost entirely from lode mining. Some of the ores are complex and contain impurities requiring special treatment. The ore mined

is rich, much of it carries from 3 to 5 per cent cassiterite. The principal mining difficulty is that the deposits are at a very high altitude. There is an export duty and a high tax on profits.

Belgian Congo. This may possibly develop into a large producer ; at present the production is between 500 tons and 1,000 tons a year.

Burma. Nearly all alluvial ; wolfram occurs frequently with the tin. About 1,500 tons are produced yearly.

China. Principally alluvial. The internal consumption is large and unknown. About 6,000 tons are exported yearly. The mineral is won chiefly by ground sluicing.

Czecho-Slovakia (formerly Saxony). A very ancient producer ; the present production, almost entirely from lodes, is about 1,000 tons a year.

Dutch East Indies. The islands Banka, Billiton, and Singkep produce together over 30,000 tons a year, nearly all from alluvial.

France. The production is very small, only a few tons a year. Tin deposits exist in a few places, but they appear to be too poor to work.

Germany. Germany can hardly be classed as a tin producing country. There are a few deposits, but the actual output is almost negligible at the present time, in comparison to other mineral products.

Indo-China. The production is about 300 tons a year ; wolfram is found with it.

Japan. The production is about 300 tons a year.

Malay Peninsula. This is the largest producer. The present production is over 40,000 tons a year. The deposits worked are chiefly detrital and alluvial ; the tin is won by dredging, hydraulicing, and ground sluicing, but some lode mining is carried on as well.

Mexico. Only a few tons a year are produced at present.

Nigeria. The present production is about 7,000 tons a year, all from alluvial. With increased use of machinery and improved transport facilities, the production is likely to grow.

Portugal. An ancient producer in a small way. There are lode deposits and some alluvial, but the present production is only about 400 tons a year.

Siam. The production is at present about 7,000 tons a year, all from alluvial.

South-West Africa. The production is very small at present. Alluvial or detrital tin has been discovered in several places, and lumps of nearly pure cassiterite from 5 lb. to 300 lb. have been found. The development of the field has been hindered by lack of water. There is said to be no difficulty about native labour, and the country is fairly healthy for natives and white men.

Spain. This country was an important producer in ancient times. Tin exists in lodes, stockworks, and alluvial. It has been much neglected of late years, and at present there is practically no tin mining going on.

Swaziland. Tin exists in lodes and alluvial. The present production is between 100 tons and 200 tons a year.

Tasmania. Tin exists in alluvial, lodes, and stockworks. The tin production of Tasmania has fallen off of late years, as some of the alluvial deposits have been worked out. There is a very great quantity of low-grade stanniferous granite, much of which may be payable at present-day prices.

Transvaal. The tin that has been won here has come chiefly from pipes and lenses ; the recent production has been about 1,000 tons a year.

United Kingdom. The West of England was for centuries the chief source of the world's supply. The present production is small, about 3,000 tons a year, but a revival is taking place. In Chapter XIII a short account is given of the history of tin mining in the West, with the reasons that have caused it to be neglected in recent years.

2. **Sale of Tin Concentrates.** It is always easy to sell, and to calculate fairly closely the price that a smelter will pay for a clean tin concentrate. The seller has always to deliver the concentrate carriage paid to the smelter's works. Here the moisture is determined and the concentrates are assayed. In the absence of any unusual impurity, the seller will obtain from the smelter a price calculated on the published price of the day, less the "returning charge." The returning charge is to cover the smelter's costs, the losses that occur in volatilization and in the slags, and to give him a profit for his work.

Before the war this returning charge was as low as £8 or £9; to-day it would be nearer £15. It is usually agreed on beforehand, subject to there being no unusual impurities. Supposing a parcel of concentrates assayed 70 per cent and the published price was £300, the cash that the seller would receive would be £300, divided by 100, multiplied by 70, or £210 *less* the returning charge and less the cost of carriage to the smelter's works. This applies to concentrates free from unusual impurities only. If wolfram is present in a quantity not exceeding 1 per cent as tungstic acid, it is probable that no deduction from the price would be made; but if it exceeded this quantity, it would depreciate the value of the concentrates, and the seller would have to agree to a small deduction. Arsenic is not found in alluvial tin concentrates, and ought to be almost entirely absent from underground concentrates before they are sold. Other impurities may be lead, copper, bismuth, and antimony. These collectively should not exceed 1 per cent. Copper can be removed by roasting, and subsequent washing, the others require chemical treatment. Silver is found in some South American ores, and it has to be removed by chemical treatment.

Tin ore concentrates used to be sent to the smelter in strong bags holding 3 cwt. It is packed into the bags wet, and the bag patted with a wooden paddle to get the concentrate to fill the corners. In the case of alluvial tin, where the bags have often to be carried on the heads of natives, it is customary to use small bags, or "pockets," holding 70 lb. Sometimes these have a calico bag inside, or a paper lining. The concentrate is packed into them dry. As black tin to-day is worth some 1s. 9d. a pound, it is important to use good bags to avoid leakage in transit. Alluvial tin ore is packed into pockets in a dry condition.

Assays used to be made by the anthracite method; to-day, either the cyanide method or the chemical methods are employed.

3. **The Smelting of Cassiterite.** This was carried out in ancient times, and up to within 200 years ago, in this country, in furnaces built of stone and clay, in which the tin was charged with an admixture of charcoal or peat. The

FIG. 11. A DREDGE OPERATING IN ITS PADDOCK
(Tavoy Tin Dredging Corporation)

fire was kept at a good heat with the aid of bellows, worked by hand, or with a water wheel. Small furnaces of much the same kind are used by natives to-day.

On the large-scale reverberatory furnaces are used. They are heated by coal, producer gas, or oil. The cassiterite is mixed with anthracite and charged into the furnace, which has already been heated. The proportion of anthracite may be one-fourth or one-fifth of the weight of the concentrates. Lime and sometimes fluor spar is used as a flux. In smelting, an important point is to have such a proportion of silica and iron, that they will combine with one another. If silica is in excess it will form silicate of tin, if iron is in excess it will be reduced and go into the tin.

Charges may be two or three tons at a time, and they are ready to tap in some eight or nine hours. During the smelting the material is stirred with rakes, the reduced metal sinks and becomes covered by the slag. When the action is judged to be complete, the furnace is tapped into a clay-lined "flote," the slag is skimmed off, and the tin ladled into moulds. The ingots are afterwards liquated, or remelted at a low temperature, the less fusible portion, which contains impurities, returning to the furnace with the next charge. Poling (as it used to be called) is done by lowering pieces of green wood into the molten tin. The gases given off by the wood cause dross to rise to the surface, so that it can be skimmed off.

The slag contains tin and is treated to recover it. Smelting is carried out on the largest scale in the Straits Settlements, next come Great Britain, the Dutch East Indies, and China. There are four smelting plants in Cornwall, but only one is in operation; the chief smelting operations are carried out near Liverpool.

If all the smelting works in the world were at work to their full capacity, they could handle about 200,000 tons of black tin yearly.

4. **Uses of Tin.** (*a*) Tin is used alone to a limited extent in the spirit and mineral water trades for tubing, and as tinfoil for the wrapping of chocolates, tobacco, etc. The collapsible tubes used for toothpaste, artists' colours, rubber solution, ointments, etc., are either pure tin or a tin alloy. With mercury it is used for the silvering of

looking glasses. It seems that aluminium foil may, to some extent, replace tinfoil, but this appears to be the only case where any substitute for tin has been found.

(*b*) Tin is very largely used as an alloy with other metals. Solders of different compositions are used for a great variety of purposes. Every motor-car uses up from 4 lb. to 10 lb. of tin, the plumbing in every house also uses up some pounds in the solder required. Tin enters into pewter (which is 80 parts of tin and 20 parts of lead). Tin is used in type metal to the extent of 8 or 10 per cent. Tin is the chief constituent of Babbitt metal for bearings, it enters into Britannia metal, bronze, gun metal, and speculum metal. British bronze coins contain 4 per cent of tin. Wood's metal, and other alloys with specially low fusing points, contain tin.

(*c*) Tin is used in the manufacture of tinplate. This is made by dipping sheets of mild steel, previously cleaned and treated with chloride of zinc, into molten tin. The quantity of tin on the surface of the finished tinplate amounts to $1\frac{1}{2}$ per cent of the weight of the plate. Tinplate is used for a great variety of purposes. The chief use is for the preservation and conveyance of meat, fish, fruit, condensed milk, and many other foods.

It is also used to make a number of articles of domestic use, such as kettles, etc. Tin is used as a protective coating inside cast-iron cooking vessels, copper vessels, and as a coating on copper and on brass wire. Terne plate is similar to tinplate, but instead of being coated with pure tin, a mixture of tin and lead is used ; it is employed for paint tins, petrol cans, and other purposes where the presence of lead is not objectionable.

(*d*) Tin is employed in the form of tetrachloride of tin, and other salts of tin as a mordant in the dyeing industry. The dioxide of tin, artificially prepared, is used in the preparation of opaque enamels in pottery work, and in certain kinds of glass.

An interesting and very complete account of the present-day uses of tin in commerce is obtained in a small book published by Sir Isaac Pitman & Sons, at 3s. It gives also the mediaeval uses of tin and the composition of many historical pieces of tin ware and of pewter.

5. **Secondary Tin.** When sheets of mild steel are

stamped or cut up to make tin cans or boxes, the blank or scrap that is left is saved to be "detinned," and the tin is recovered either as metal or as a salt of tin. A certain quantity of old tins are also collected and treated. The treatment of the clean scrap is easier than that of the old cans, as the scrap is clean. The old tins are dirty, sometimes oily, and many have labels or varnish on them. Both scrap and old cans have to be cleaned, and then baled by hydraulic pressure, and then unbaled on reaching the detinning works. Tin can be recovered from them by the action upon them of chlorine gas, under pressure at a low temperature. This removes the tin as stannic chloride, and the steel is left unattacked.

Tin can also be dissolved off tinplate by boiling with a solution containing caustic soda and nitrate of soda, when sodium stannate is produced. Another method is to expose the scrap in a bath of caustic soda, and to deposit the tin electrolytically on sheets of tin. The recovery of tin is said to be a business which requires much technical skill and experience, as well as a considerable outlay in plant. It is not possible to make it remunerative on a small scale. So far, it seems to have been chiefly confined to the treatment of the clean scrap.

The reason why the collection of the old cans is not more generally carried out is that they are so bulky that they cannot be transported without baling. Where they can be collected in large and regular quantities at a small cost it pays to sell them, so that it is likely that their collection will become more general in large towns. But even if this is done, it does not seem possible for it to have much influence on the world's requirements. At present it appears that the amount of secondary tin, produced throughout the world from scrap, is between 6,000 tons and 7,000 tons. Detinning is practised in America, Russia, and elsewhere.

6. **The Price of Tin.** We know very little of the price of tin in early times, but the price of tin in recent years will be found in the Memoirs that accompany the maps of the Geological Survey.

For instance, the Memoir on the Falmouth and Camborne districts (1906), gives the price year by year from 1750 to 1906. During this period the production shows a

fairly regular increase, but with a number of fluctuations. Until mechanical aids came to be employed on a large scale, the price of tin bore a fairly close relation to the cost of living, as it was a question of the manual labour required to extract it by washing the detrital matter of the valleys, or later to mine and prepare it for market. The price of all minerals depends on two things: (1) the cost of producing them, and (2) the demand.

If the supply is at any given time seriously greater than the demand prices must fall, as in fact the price of tin did, with very disastrous results, to the home industry. At the present time (1927) the price of tin is considerably above the cost of production, that is to say, above the cost of production in properly selected and well-managed tin mines. This will naturally enable many tin mines to pay profits, and will cause fresh deposits to be sought for, and existing ones worked much more vigorously, than if the price were low. It may be that over-production will result. If so, it will be a case of the survival of the fittest, that is, those mines which have been carefully selected for economical working, so that there is a large margin between the cost of production and the selling value of the concentrates. It is, therefore, advisable to base calculations not on to-day's price, but on what it may be in two or three years time. Probably it is safe to base calculations on £250 for tin (the metal). Some tin mines would weather the storm whatever the price. Such cases would be those adit mines where there is no expenditure for pumping, or pumping mines where there is water-power for all purposes, so that running expenses are very small.

In an adit mine flooding is impossible, and if all work had to be stopped it can be resumed on a full scale directly the price enables a profit to be earned. In a deep pumping mine, if any cause stops the pumps, the mine will flood and the cost of restarting may be a very serious matter. For instance, there are well-known mines which are closed to-day, not because there is any doubt as to the existence of payable mineral, but simply because the cost of unwatering and reconditioning them would be so great that no one has the courage to try and collect the funds to reopen them. Many of the large alluvial mines produce

tin so cheaply that it is impossible to conceive of any circumstances in which they would not be making profits.

In tin mining (as in all mining), mines are worked in competition with each other, consequently if very large discoveries of tin were made, so that the metal was produced more quickly than the world could consume it, the price would fall, and some of the weaker mines would go to the wall. This may still happen, though it is much less likely to happen at the present day, seeing that consumption has increased and steadied. Most of the tin areas of the world are now fairly well known, and it is very improbable that the market will have so much tin rapidly thrown on it as to depress the price below £250 for metal. On the other hand, many of the alluvial deposits (from which the bulk of the tin is obtained to-day) are becoming exhausted. Undoubtedly new payable areas will be found and worked, but the supply of alluvial tin is not unlimited, and there is every reason to believe that the demand for tin and its use will extend rapidly every year. We must expect, therefore, something in the nature of a world shortage, and it is quite possible that the average price for the next few years will be over £300 for metal, and the time may not be far distant when £350 may be a regular figure.

CHAPTER XI

1. *The necessity of business-like methods in the mining industry*—2. *The selection of properties to work, from a careful consideration of:* (*A*) *Engineers' reports;* (*B*) *Local conditions of the deposit;* (*C*) *Demand for and price of the metal;* (*D*) *Price asked for properties;* (*E*) *Conditions of lease, royalties, taxes, export duties, etc.*

Many textbooks on mining devote their attention chiefly to the technical side, but the business aspect of mining, as an industry, deserves quite as much attention as the technical details.

This book only professes to be a guide (not a textbook or complete manual), and I only attempt to deal with the matter on broad and simple lines. But in any guide to mining it is essential to point out the lines on which it must be conducted in order that it may be profitable.

Unless a mine pays good and regular dividends, and the capital is repaid to the investors before it gives out, we cannot call it a really profitable undertaking.

It is common knowledge that it is not easy to raise capital for any mining undertaking, except possibly for persons who are able to point to several successful undertakings which they have brought into being. Numerous failures have given the industry a very bad reputation. Every case where a mining undertaking results in loss, or very poor returns, checks the free flow of capital essential for the proper conduct of the industry. That it should be so is a grave misfortune. Many qualified miners and some very competent engineers are at present unemployed, and the revenue which is being derived from the mineral industry is very much less than it should be. This applies to mining all over the world.

The chief reason is that the general investor has a deeply-rooted distrust of mining, because the successes bear such a small proportion to the failures.

This state of affairs can, and must be, altered before the industry can flourish. An abundant and regular supply of all minerals at reasonable prices is essential to our well-being as an Empire.

To place the industry upon a proper basis requires the

active co-operation of the miner, mining engineer, promoter, directors, and investors. Each of these can contribute to the success of the industry as a whole, as well as to their own personal advantage.

The main point to keep in view is that a mine must be worked as a *business*, the aim of which is to make a profit. The shares must have a real value, and not be regarded as gambling counters.

The problem is a difficult one, and in order to present it in a clear manner I have divided it into sections, setting out the difficulties and how they may be met.

In the first place we need to restore the confidence of the investing public. This can only be done by "making good."

There are an enormous number of mineral deposits of all kinds, some are rich enough to pay to work, but most are not. To distinguish (as far as possible) between the two classes, reliance must be placed on the reports of engineers, and on a careful consideration of the local conditions under which the deposits occur, and on the present and probable future demand for the mineral in question.

Finance must be obtained sufficient to bring the property to a paying stage, skilled staffs must be secured, and the property must be worked energetically and economically.

The Selection of Mineral Properties

(*A*) Engineers' Reports.

Groups who have been concerned in mining finance for several years, are in a better position to select payable properties than those new to the industry. They have at their command experienced mining engineers whose reports can be relied on, and have also knowledge of the various difficulties that are met with in mining. With this knowledge, which has generally been acquired as the result of large expenditure of money, patience, and energy, they are less likely to attach an imaginary value to any particular property, are more careful to criticize and investigate it, and, in short, act with more prudence than persons of less experience.

It is their practice, after examining any reports on a property offered to them, to have these reports confirmed, or otherwise, by independent engineers of their own choosing. In this way they often detect weak points in properties offered them, which might seem attractive to persons of less experience, Moreover, those who have brought one or more properties to a successful issue are asked so frequently to purchase or finance other properties, that they have a wideness of choice and a means of comparing the merits and disadvantages of various properties, which does not exist in the case of others.

There is no statutory qualification for mining engineers. Anyone may call himself a mining engineer, and the fact that he belongs to a given society, or has qualified at a mining school, does not in itself make him an authority.

Strict conscientiousness, and long practical experience, are the real qualifications. By this I do not mean in the least to decry the advantages of a mining school education, but to point out that without long practical experience, this education is not sufficient to enable a man to report on mining properties. The technical side of mining cannot be learned without experience in mines, and the practical miner is sometimes a better mining engineer than a man with more education but less experience.

Mining engineers' reports are used for two purposes: first, to enable a decision to be arrived at as to whether a mine is worth working ; and secondly, when favourable, to assist in inducing investors to provide capital.

As there are so many mineral deposits which are far too poor to pay, and only a few likely to be payable, it is necessary that the engineer employed to report on a mine should be able to distinguish (so far as it is humanly possible) between mines that are likely to be profitable and those that are not. To form an opinion on any given property means a considerable amount of real hard work in sampling and investigating. To do this honestly may occupy a considerable time, but, seeing the extreme importance of correct conclusions. the time and labour must not be grudged.

Reports should state first of all, in the clearest possible manner, all the facts ascertained regarding a given property, and then the conclusions to be drawn from these facts.

The local conditions under which the mineral deposit occurs should be stated, and all circumstances bearing on its profitable exploitation should be noted. Every mining proposition has its advantages and disadvantages. These should be impartially enumerated and commented on. In the case of some properties, it is possible to say at once, "this cannot possibly pay," while it is very seldom that the converse can be stated, unless, as in alluvial ground, the whole depth of the ground can be explored. Where lode propositions are concerned, the most careful and skilled examination can rarely afford a certainty of the payability of a property, but it can distinguish those *likely to pay* from those which are *merely possibilities*.

Just as an alluvial property must be tested by pitting and boring before any real knowledge can be gained of its value, so a lode proposition must be sunk on or tunnelled.

We cannot judge of a lode proposition in depth from samples taken on the surface ; any conclusions arrived at from surface samples are prophecies, and not certainties.

It is true that with long experience, a consideration of the geology of the district and the results of neighbouring mines, and the fact that lodes which have been profitable close by can be proved to traverse the property in question, such prophecies may be based on a logical foundation, but these considerations do not make them *certainties*, for actual exploration alone can reveal the extent and value of the ore.

An engineer's report, then, must usually consist of a series of actually ascertained facts, and conclusions drawn from these facts.

The facts are actual, definite, and as far as assays go, must be founded on figures ; the conclusions are partly, at least, in the nature of forecasts of what may reasonably be expected to be found, in the light of the knowledge available at the period of examination.

But the engineer's work in reporting on a property does not finish here ; he should show by calculations whether the property is commercially worth acquiring, equipping, and working. To do this he must first take account of the ore in sight, then of that likely to be obtained on further development, the cost of its extraction, preparation, and marketing. *He must ascertain beyond doubt that*

Fig. 12. A Dredge at the Works of Malayan Tin Dredging, Ltd.

a marketable product can be made by known and proved methods, and he must state the price at which he expects it can be sold. This is not easy, because the prices of most minerals vary greatly, so that a liberal margin must be allowed for falls of price, rise in the cost of mining, unforeseen contingencies, and the like.

An engineer's report should be full, clear, and accurate, and should show all the technical details on which his conclusions are based. It should contain all the technical details that are required by another engineer, to see that a full investigation has really been made, but it should be couched in perfectly plain language, and free from unusual phrases, so that anyone who reads it can have no doubt of its meaning. The ideal report should be as clear to a non-technical shareholder as it is to an experienced director. This is most important, for if the prospective investor studies reports and prospectuses, he can soon form a good idea of the safety and value of the investments offered to him, and as soon as he has attained the habit of critical selection he can judge which projects are sensible commercial risks, and which are mere gambles.

I give next the general information which ought to be found in a report. In many cases there are further details which should be included, but none of the following information should be omitted, for every single point has a direct bearing on the payability of a property—

1. Full details as to how the area or mineral rights on the area are held, whether freehold, by licence or by lease, the royalties, rents, or payments for surface damage, export taxes, etc., that are involved.

2. The labour available, whether trained or otherwise, and the local rates of pay.

3. The climatic conditions, duration of the wet and dry seasons, and average amount of rainfall.

4. The position of the deposit in relation to roads, rail, navigable rivers or seaport, and cost of transport.

5. The amount of water available for power or dressing operations, and its seasonal variations.

6. The fuel and food supplies available, etc., etc.

(*a*) *In the Case of Lodes.* 1. What mineral has been found, and what impurities accompany it.

2. The general percentage found, and the *proportion*

that can be recovered by ordinary practical working methods.

3. The distance that the lodes have been traced, their number, and average width.

4. An assay plan should be submitted showing where and at what depths samples were taken, and a statement as to how, when, and by whom they were taken, with duplicate samples, should accompany the plan.

5. A description of the country rock, and whether any changes of strata are noticeable.

6. If the lodes are entering a hill the approximate height of it should be given.

7. The kind and amount of timber that is available for underground work, surface work, or for fuel.

8. The approximate cost of coal, wood, or fuel oil delivered on the spot.

9. The distance from towns where ordinary mining stores are obtainable, and the distance the mineral product will have to be sent to be sold.

(*b*) *In the Case of Alluvial Deposits.* 1. The mineral that has been found, and its degree of purity when dressed by methods ordinarily employed.

2. The average depth of the ground.

3. The values found should be shown on an assay plan, with the depth of the pits or bores.

4. It should be stated how the samples were taken, whether the values stated were obtained by washing the *whole* of the dirt from pits or bores, or whether portions of the dirt only were washed, and by whom and at what dates.

5. Whether much clay is present.

6. What water supply exists, and how it is affected by the season of the year.

7. Whether it can be brought on by gravitation, the distance from which it would have to be brought, and the head that would be available.

8. Whether the ground is under water or water-logged during part of the year.

9. The nature of the bottom, whether soft, hard, or uneven.

10. Whether the area is encumbered by large trees or close bush, or contains buried timber, or large boulders.

11. Whether heavy floods or prolonged droughts occur.

12. What facilities exist for the deposition of tailings, and whether they are allowed to enter water courses.

An engineer's report should contain clear statements as to the *quality* of mineral which he considers the property will yield, and give the quantity per ton or per cubic yard.

This information cannot be arrived at by *analysis alone* ; milling and concentration tests are essential to ascertain the *recovery*, which is always much lower than the assay value in ore which has to be milled and concentrated. The engineer should state the *quantities he has dealt with in order to arrive at his conclusions.*

He should specify the nature of the plant that he recommends as necessary for the effective working of the property, how long it will take to erect, and its capacity, and should show his calculations of probable working costs and the profits to be expected on the grade of ore as at present disclosed.

An examination of a number of reports by mining engineers will show that while some give all this vital information clearly and in full detail, others omit many important items, and sometimes contain much irrelevant matter, or forecasts of high profits, for which no sufficient evidence is adduced.

(*B*) Local Conditions.

It has been mentioned above that a report should state clearly the conditions under which a mineral deposit occurs, and as the local conditions of a deposit have a profound bearing on its practical value, it is worth considering some of these conditions in detail.

Transport. In the case of bulky ores, such as zinc, copper, and iron, the distance from rail or water transport is a very important item. In the case of those which are concentrated on the spot, such as gold, silver, mercury, tin, etc., the concentrate is valuable enough to stand a relatively high transport charge. In addition to the original cost of transporting plant, sometimes to places difficult of access, there is a constant charge for the transport of the finished article, for stores, for replacements, and for the necessary journeys of the staff.

Climatic Conditions. It is always more expensive to

work a mineral deposit in the Tropics, for the European staff need higher pay and more frequent holidays, their journeys home have to be paid for, plant, stores, and replacements have to come from a distance, and both wood and iron work, particularly wire ropes, boilers, and rails, deteriorate rapidly.

In dry countries there may be difficulties owing to the scarcity of water ; in wet countries heavy rain hinders outdoor work and necessitates heavy pumping charges, and often the use of much underground timbering.

In very cold climates the ground may be frozen during several weeks in the year.

Some tropical districts are unhealthy. This means loss of working time through sickness, and sometimes the staff has to be replaced so frequently that the additional expense is a serious item.

Some countries are liable to severe storms, forest fires, tornados, and floods. In others snow prevents outside work for weeks at a time.

Fuel Supply. This has been dealt with in Chapter IX on " Power for Mining," but is mentioned here to draw attention to the fact that any local conditions, such as snow, floods, forest fires, that are liable to interfere with the regular supply of power, may be a serious obstacle to regular working.

Labour Costs. These form perhaps the most important item among the local conditions that govern the payability of a mineral deposit.

Roughly speaking, the expenditure on salaries and wages is generally from two-thirds to three-fourths of the total expense of mining.

This subject is dealt with under " Mining Costs." but is mentioned here for two reasons: first, to warn the reader against believing that because low wages may be paid to natives in some countries, such labour is *really* cheap, for it often is not, on account of small performance and excessive cost of supervision ; secondly, to warn everybody against investing money in countries and districts where agitators are allowed to foment trouble.

Mining pays if properly conducted, but there is no margin for half-hearted work, or interruption due to strikes.

Political Insecurity. In some countries the government is unstable and taxation may vary. As in the case of places where labour is unsettled, it is safer to leave such countries alone altogether, for there are so many mineral deposits from among which to choose, that it is wiser not to touch those where any one of the essential local conditions is obviously a source of potential danger.

(*C*) Demand for and Price of Minerals.

There are at present only a few metals and minerals where some control is exercised by members of the industry themselves, as regards price and placing on the market: gold, diamonds, bismuth, and platinum.

Taking them separately, diamonds are marketed through a pool, and when the demand is low production is restricted. Bismuth has a more or less steady demand ; it could be produced in much larger quantities. Gold is sold through a pool ; a certain quantity is sold to the Mint, and a certain quantity to trades using it. Quicksilver is also regulated ; in this case there are comparatively few producers.

My object in drawing attention to the fact that some regulation has been found commercially practicable, is to urge that some such control would be advantageous in the case of most mineral productions, and save losses of capital and unemployment, because we should not be acting on guesswork, nor on doubtful predictions of the value of given minerals, that is, we should not be so subject to capital losses through indiscriminate marketing of mineral from new discoveries, with serious or fatal effect to deposits of average merit, which pay under normal conditions. The instances of the injury to tin mining, due to the falls in price owing to discoveries abroad in 1875 and 1895, will be familiar to all.

(*D*) Price Asked for Properties.

The discoverer of a mineral deposit is nearly always confident that he has found something exceptionally valuable, and is apt to neglect any difficulties or disadvantages that may exist. Enthusiasm is a good thing in its proper place, but it is entirely out of place in selecting or valuing a mineral deposit.

In seeking to interest others in his discovery, the discoverer or owner of a mineral deposit must realize that no experienced person will pay attention to an alleged discovery unless definite evidence is produced, not only that a deposit of a commercial mineral has been found, but that a *strong prima facie case can be made out for its being profitably workable, even during periods of low prices.*

The more complete and accurate the information is on all matters affecting its payability, the better chance there is of serious attention being given to the discovery by *those able to provide funds.*

The discoverer must remember that no matter how convinced he may be in his own mind as to the value of his property, he has to convince *others*, who have probably had a wider experience than his own of the difficulties and risks that attend the financing and working of mining ventures, and who are asked almost every day to take part in some new undertaking.

Leaving out of consideration the great number of mineral deposits that are too small or too poor to be of any practical use, we may consider mineral deposits under two headings—

1. Those that are rich enough to enable ore or concentrates to be sold at a profit *from the commencement*, with simple and inexpensive plant.

2. Those where ore or concentrates *cannot be mined or sold without the provision of extensive plant*, but where there is evidence of the existence of ore, and a strong probability of its continuity under conditions which should pay well if worked with adequate capital and plant.

1. In the former case the discoverer may be able to open up the deposit, work it, and provide himself with additional or improved appliances as he goes on. If it turns out to be large enough to justify company working, the records of these sales will be of great assistance in obtaining financial aid on reasonable terms.

2. The majority of mineral deposits require more plant and working capital than can be provided by their discoverer, and hence he has to offer the property for sale or to seek financial aid, as soon as he has tested the deposit to the best of his ability.

Before seeking financial assistance, he should collect all the information which will be needed to enable a preliminary opinion to be formed on the practical utility of his discovery.

If the discoverer of a deposit can get advice from a mining engineer during the early stages of his work in opening up a new discovery, he should do so, as it may save him from wasting time on a deposit that could never be profitable, or enable him to prove it more quickly than he could have done by acting on his own initiative alone.

In any event, he should note down and consider all the points mentioned under the heading of "Engineers' Reports," and any other circumstances bearing on the economical working of the deposit.

Some failures are unavoidable, even with properties that have been carefully tested, owing to natural and inherent risks in mining that cannot be entirely eliminated, such as the loss of lodes through faults, or a change or falling off of their mineral contents, or severe and prolonged depression of prices. The last-mentioned risk can be guarded against by selecting properties on which work can be resumed without large additional expenditure, if it has been necessary to suspend operations for a time.

(*E*) Conditions of Lease, Royalties, Taxes, Export Duties, Income-tax, etc.

In the first place, it is necessary to obtain and study the maps, plans, and title deeds, so as to get a clear knowledge of the location, boundaries, and actual ownership. Regarding the latter, the opinion of a solicitor and, if necessary, counsel, should also be obtained.

The licence, lease, or deeds, and agreements must be carefully examined.

Most licences and leases granted by governments are fair and straightforward, but they sometimes contain oppressive clauses, and in some countries additional taxes are imposed that may not be set out in preliminary documents.

Where leases are granted by private individuals, it is most necessary to be sure that the *grantor has power to grant*, and that there is no one over him who ought to have been consulted first. Some of the old leases granted

in the United Kingdom used to contain elaborate restrictions, arranged for the benefit of the mineral landlord, which bear heavily against the grantee.

Licences and leases or options should be drafted by the solicitors of both sides, and finally explained and agreed on while their principals are present, and the engineer and directors of the mining group should carefully consider how each clause will operate.

Most mineral landlords are willing to grant reasonable terms for the exploitation of minerals on their estates.

The royalties charged at the present day are usually about 3 to 4 per cent of the actual selling value of the ore prepared for sale at the mine.

In all cases it is advisable to get clear information as to boundaries and titles, and royalties and terms, before an inspection is made. In this country it is customary to obtain a licence for a short period (say, a year) from the mineral landlord. This licence usually requires some testing work to be done, and if its conditions are complied with, and the licence holder shows that he has the means to work the area effectively, a lease is granted on his application, for a period of years.

It is customary to charge a small rent and a royalty on the mineral raised while the area is held under licence ; when a lease is granted the minimum rent is usually higher, and there are ordinarily clauses to the effect that work must be carried on regularly, that the ore must be dressed on the mine, and that the mineral agent to the landlord must be informed before sales are made. The holder of the licence, or lease, is also responsible for keeping shafts or cuttings duly fenced ; he must not cover up land with dumps or tailings unless he has permission to do so, and he must not pollute water courses.

In most cases, he is given permission to use or divert water courses, make tram roads, and do all acts necessary to the miner-like working of the area. He is usually required not to do anything that would interfere with the farming or sporting rights, and if he requires to occupy surface (other than waste land) he may have to pay separately for it. During his period of licence or lease he agrees to give the mineral landlord's agent facilities for inspecting the workings, the stock of mineral and the

plans, and on relinquishing the sett to leave it in good order. Sometimes there are clauses to the effect that before removing any plant, he shall offer it to the mineral landlord. He will probably be required to pay local rates, but there is no Government tax on tin raised in the United Kingdom, whereas in some other countries heavy royalties are charged.

Before attempting to form a definite opinion as to whether a particular property has merits, those to whom it is offered should see whether they have enough evidence to form a preliminary opinion of its payability, for there are many points to consider. Next, if they are wise, they will have it examined by a reliable and experienced engineer. If his report is favourable they should consider the local conditions of the deposit, point by point, and endeavour to see if there are any weak points that were not apparent at first sight.

Unless a particular proposition can be shown to have real merit, it is better to have nothing to do with it, for there are plenty of mineral deposits, and only a few have real merit.

It is best to play for safety by dealing only with properties where risk is small. As an illustration, take the case of an alluvial property which has been properly tested by pits, bores, and paddocks, and is proved to contain 2s. worth of recoverable and saleable values per cubic yard, with a regular supply of water under gravitation, and no difficulty in disposal of the tailings. Or take a lode proposition, which can be worked by adits, so that there is neither pumping nor hoisting, and the lodes crossing the hill have an average width of not less than 3 ft. to 4 ft., and an average value of not less than 30s. per ton of recoverable and saleable values. Here the risk is obviously less than in a shaft mine, where there must be a permanent charge for pumping.

In both of the above instances we are still faced with the risk of fluctuation in the price of the mineral. But one cannot expect to find the " perfect mine " in which nature has given us each and every condition in our favour. All that is humanly possible is to make such a *selection* of properties as to eliminate all the risks that can be eliminated.

It will assist the reader to realize the risks of mining if I state the causes which I have seen to result in failure in some mines—

1. In several cases plants were put up, tram lines made, houses built, water courses cut, and then it was found that there was practically no ore worth treating.

2. In another case alluvial ground was taken up, large expenditure incurred in machinery, roads, and dams, and the alluvial which had been reported to contain 10 lb. of cassiterite per cubic yard, and to be an average depth of 6 ft., really contained less than 1 lb. per cubic yard, and the average depth was less than 2 ft.

3. In another case, what was actually milled and bagged as cassiterite only contained 20 per cent of cassiterite, the rest was garnet and chalybite.

4. In several cases there had been lavish expenditure on surface, and so little underground exploration that the mine could not be tested for want of capital.

5. In more than one case an ore (supposed to be silver-lead) was such a complex mixture that there could be no margin for profit.

6. Fluctuations of prices have closed many mines.

7. Unforeseen difficulties, such as attempting to work alluvial matted together with thick bush; in another case a "boulder pack" of large stones prevented the mineral from being got out. The stones were too large and numerous to move.

8. Excessive wages closed down several mines. They flooded, and it was not possible to recommend their reopening.

9. The cost of pumping, in the case of very wet mines, is a common cause of loss of capital. Even where capital is not lost, the pumping charges may eat up nearly all the profits.

In almost all these cases the directors had been misled by careless and insufficient reports, but they were themselves also to blame for neglecting to verify information before spending their shareholders' money.

A great many similar mistakes will be within the knowledge of many of my readers, but I mention these cases because very similar mistakes are often repeated. I do not pretend that I have touched on every possible cause

of loss ; *each property presents its own peculiar difficulties, and must be dealt with and examined on its own merits and demerits.*

Assuming that a property has been carefully selected from among a number of others, and after adequate testing is proved to contain payable ore, and the price asked for it is reasonable, we come next to the questions of the management and finance.

CHAPTER XII

The management of mining companies and mines—Mining finance—Mining as an investment

Most mines of any importance are worked by companies. Companies are managed by directors, the number, qualification, and remuneration of whom are generally regulated by the articles of association. The directors are appointed by the shareholders.

The directors appoint the staff and supervise the affairs of the company. The most important of the office staff is the secretary, who attends all meetings of the board, prepares agenda, sends out notices, conducts correspondence, and keeps the books, etc.

A statutory meeting must be held not less than one month nor more than three months after the incorporation of the company.

A general meeting must be held not less often than once a year, at which the accounts are submitted, and the directors report to the shareholders the position of the undertaking.

When a shareholder sells some or all of his shares the transfer must be entered by the secretary, and a transfer fee is payable to the company. A list of shareholders is kept by the secretary, and a duplicate list at Somerset House. This may be inspected by any person on payment of a fee of one shilling.

At meetings each shareholder can vote, or can send proxies signed by him in favour of the directors or of another shareholder. If the shareholders are dissatisfied with the action of the directors, they can require the directors to call an extraordinary meeting.

The directors' actions, however, are more frequently criticized at the annual general meetings, when a certain proportion of the directors have to offer themselves for re-election. This gives the shareholders, if they are dissatisfied, the chance of replacing the retiring directors by others in whom they have more confidence. A retiring director can be got rid of by a bare majority; whereas

if an extraordinary general meeting is called to remove him before his time is up, a three-quarters' majority is required.

Directors' Qualifications and Duties.

It is usual that the qualification of a director consists in the holding of not less than a certain number of shares. His duties are to attend meetings, consider the reports sent from the mine by the manager, and see that the shareholders' interests are guarded in every way, and direct the affairs of the company generally. Sometimes directors of mining companies have a knowledge of the technical details of mining, and it is very desirable that they should have such knowledge, for without it they can hardly be expected to appreciate the manager's reports, and assist him in overcoming difficulties, or realize where money should be spent, and where economized.

Any competent man of business can soon acquire a general knowledge of the functions of a director, but it is not fair to shareholders if a man accepts office and does not set himself to master the details and requirements necessary to the success of the property he is directing.

A competent manager at the mine, unless backed up by a competent board, is heavily handicapped. The main thing that the directors should insist on is to get frequent and clear reports of the progress and expenditure, and immediate information of any unexpected difficulties, so that means may be adopted in good time to overcome them.

Directors should resist the temptation of sending people out to the mine because they are relatives, and they should not permit the circulation of reports intended to cause rise or fall of the quoted value of the shares, but should keep the shareholders acquainted with the true state of affairs by the issue of regular reports at reasonably frequent intervals.

They should create a reserve fund, particularly in the case of mines where the mineral which is being mined is subject to variations of demand and price.

It is very desirable that one or more of the directors should visit the property from time to time, so that they

FIG. 13. DRESSING CONCENTRATES ON THE DREDGE LAUNDERS
(*Tavoy Tin Dredging Corporation*)

may confer with the manager and have a first-hand knowledge of the problems he has to meet.

The Mine Manager and His Duties.

The mine manager is the most important employee of a mine, whether it is worked by a company or an individual. The main function of a mining board might be said to be to get, keep, and supervise a competent manager. The mine manager is responsible to the directors for the proper, economical, and energetic working of every department.

He should be a man of strict conscientiousness, active, experienced, and with wide knowledge of his profession. In engaging and dealing with men he should possess a good knowledge of human nature, as well as of mechanics and chemistry.

As has been previously pointed out, there are but few rich, shallow, easily worked deposits at the present day, and there are no mines which will stand ignorant and careless management. The energy, efficiency, and character of the manager are reflected among the whole of his staff. If he is keen and competent, good tempered, and takes an interest in his men, he will attract and keep good workers.

There are a great variety of duties which he may have to perform in a small mine, or supervise in a larger one. The chief of these is to develop the mine in such a way that a regular and increasing output may be obtained with safety and economy. Conditions vary so much in different mines that a great deal depends on the individual adaptability of the manager to see where improvements and economies can be effected, and to get them made without friction.

Where funds permit, the manager should have a deputy, who can take his place in emergency, and can assist in the investigations mentioned above. It is important that the manager himself should (like the captain of a ship) not be burdened with too much personal routine work, for his attention has to be given to a great variety of matters, all of which bear on the effective exploitation of the mine, and in particular to the problem of reducing the costs of every stage of his operations. This constant endeavour

to reduce costs must be made without picking out the eyes of the mine, or leaving places dangerous, or neglecting repairs. It must be done without souring the men, and must be a *progressive, not spasmodic*, movement towards economy and efficiency.

The main point is to ensure that everyone on the mine shall know his duties, and shall be in the frame of mind to do his best. This frame of mind cannot be induced merely by the fear of dismissal if he is found neglecting his work. At the present time there are few positions in any mine which can be highly paid. But pay alone is not the chief inducement to good workers to do their best. Appreciation of steady application, constant care for the safety and comfort of all workers, and promotion when possible, appeal to everybody.

Idlers or grumblers should not be retained among mine workers, and the manager will be well advised to get rid of them. It is much better for the manager (where possible) to engage his staff personally, for if they are sent to him on an agreement for a period, he cannot easily discharge men who are unsuitable.

The effective work that men can do depends very much on their being kept in good health. This is all the more important in tropical and semi-tropical countries. In large mines abroad there is often a doctor on the staff; if there is no doctor, the manager should see to the provision of first-aid appliances, medicines, proper food, housing, and general sanitation. If he takes a keen interest in these matters he will find it quite possible to induce a like interest among his men.

It is important in isolated places to try and provide occupation and relaxation for the men during the hours when they are off duty.

A reading room and a library, and the outfit for indoor and outdoor games are useful assets.

Mining Costs.

It is one of the manager's most important duties to keep these as low as possible, and comparison with the costs on other similar mines is a useful test. The costs should be worked out per ton of ore broken, and also on the weight of the finished concentrates. In order to find

out where improvements can be effected, the manager should consider each operation separately, e.g.—

Driving, so much a fathom.
Sinking, so much a fathom.
Stoping, so much a fathom.
Tramming, so much a fathom.
Hoisting, so much a fathom.

Milling, concentrating, bagging, and transporting to market should be similarly dealt with. Similar figures should be worked out in the case of an alluvial property.

The object of this " costing " (as it is called) is to find out where the cost or any part of the cost of any operation is higher than it ought to be. When this is ascertained it can be considered what means can be adopted to reduce the cost.

Increasing Output.

The quantity of ore broken and trammed, and the quantity of waste rock picked out should be recorded daily. The amounts will naturally vary occasionally ; the causes of such variation should then be ascertained. All delays and stoppages of machinery should be looked into, for slight defects can then be remedied while they are still slight.

Next to increasing output up to the full capacity of the plant comes the question of the effectiveness of the treatment. In every mine some values pass through the plant and go away in the tailings. The tailings should, therefore, be watched carefully and must be frequently assayed. No outfit is ever perfect ; there is always a chance of getting a little more out of the tails, or of improving the various methods of treatment, whatever they may be.

Ventilation.

The ventilation of metallic mines is very often not as good as it could be made. The manager or his chemist should attend to this.

It is not only a question of safeguarding the men's health ; in poor air an adequate amount of work cannot be performed.

Plans and Surveys.

These should be adequate but not needlessly elaborate. The objects of surveys and plans are various. A surface plan of the property is required to show the boundaries, position of roads, railways, water courses, buildings, tramways, and plant.

Underground plans are required to show the relative positions of shafts, stopes, and drives, and of old workings where water or loose ground may be encountered. Simple plans, showing the position and probable trend of the lodes and their values, are required for the purpose of making clear to directors the reason for extensions, and the ground already worked and being worked. In these plans the values should be marked in figures or indicated by colours.

Relation of Output to Standing Charges.

There are 8,760 hours in the year, during which pumping and all the other ordinary overhead charges are going on. If only one shift is worked the *actual mining* will, in most cases, be carried on for eight hours on five days in the week, and four hours on the Saturday, but these figures include the journey from the changing house to the face and a meal-time, so that the *actual* work may not exceed 36 hours a week.

By employing a second shift a gain of tonnage is obtained. Men employed on afternoon or night shifts are paid (usually) the same as the day shift, but work about four hours less. In some cases it would be an advantage to employ a second shift, if the ventilation is sufficiently good, so that they are not delayed in getting to work by waiting for the smoke to clear away. There might be cases where it would be an economy to employ a third shift, as, for example, if the pumping charges are very heavy, but in most tin mines it would be a difficult matter to arrange adequate ventilation. The main point to bear in mind is that the whole problem of mining is to get the greatest possible quantity of ore at the lowest possible cost, so that careful consideration is required as to the question of how to break the ore most cheaply. In driving ends where it is important to open up fresh stopes,

or in cases where it is important to get through so as to secure better ventilation, it is undoubtedly advisable to work three shifts.

Regulation of the quality of ore going to the mill can be secured in patchy mines, if it is possible to keep a number of stopes open so that there is a choice of places to take ore from. In the case of a tin mine, where some of the lodes carry accessory minerals, those lodes should preferably be worked when such accessory minerals are fetching a good price. When tin is high in price it is possible to mine and mill lower grade ore than could be worked when the price is lower.

Plant.

It is advisable that the plant should be able to deal effectively with all, or a little more than all the ore that is normally being mined. In the majority of mines the profit per ton is comparatively small, and it is necessary therefore to put through a large tonnage. It is always a stimulus to the miners if they know that the mill can deal with the ore as fast as it can be got out; in fact, it is better to be constantly calling for more ore, to keep the mill going, than to allow the production to be sufficient to keep the bins full. Mill stoppages are bound to occur sometimes, so the capacity of the mill should be such that it can always very quickly clear off any accumulation of ore. In the same way the treatment plant that deals with the ore after it has left the mill, should be adequate to deal with a little more than the daily flow of sand and slimes.

The manager should insist on every appliance being kept in first-class working order. If things work loose, there is injurious vibration, loss of power, and waste of mineral. Lubrication must be carefully attended to, bearings being kept covered against dust and mud, and no oil or grease allowed to escape on to the floors or the ore.

Buildings.

The roofs should be periodically examined for leakage, and cross-tyes and supports should be kept in position. Good natural lighting is important in the daytime, and adequate artificial light in night-time. In the Tropics,

where tornados occur, buildings must be stronger than is needed in temperate climates.

Protection Against Fire.

Hose must be kept in order, inflammable stores protected and kept away from main buildings. Bush should be kept cut or burnt off in a belt round buildings sufficiently wide to afford protection against bush fires. Lime and carbide must be stored where they cannot be wetted. Regulations regarding the maintenance and use of magazines must be carefully observed.

Managers' Reports.

The manager usually submits reports to the board at regular intervals—weekly, fortnightly, or monthly (or in the case of mines abroad) whenever there is a mail. This should not, of course, prevent him from communicating with his employers at once as to anything specially important. At the end of each year it is usual for him to submit a detailed review of the year's operations. This review (or more frequently a summary of it) is circulated by the directors to the shareholders with the accounts of the company. Sometimes the manager's report is not circulated to the shareholders generally, but a certain number of copies are made and supplied to such shareholders as specially ask for it. There is reason in this, for the manager's reports necessarily contain a good many technical details which would not appeal to those investors (unfortunately a majority) whose interest in the company's operations is limited to the amount of the dividend, or to the quotation of the company's shares, and who will not trouble to examine whether the quotation is justified or the dividend properly paid.

Mining Finance.

This may be required—

1. For the initial expenses of securing reports and testing one or more properties.

2. For the working of a property after such examination and test have shown that it is worth working.

1. It has already been pointed out that the examination of a mineral deposit must be carefully and critically

conducted. Mere inspection alone in many cases does not suffice, for often there is essential work that must be done before samples can be taken. Wherever it is possible, *actual working* of a lode property, or an alluvial property, is of great value in establishing facts as to the extent and treatability of the ore.

This means that funds must be available for such testing and working *before* any attempt is made to form a company. It is somewhat harder to obtain this preliminary finance, because until a mine has been thoroughly examined there is no saying that the money spent on it may not be lost.

It is, therefore, often necessary to form a syndicate to acquire an option for a period within which the examination can be carried out. The cost of obtaining a report on a mine naturally varies with the standing of the engineer employed, the length of time he is engaged on the work, and the amount of boring, pitting, sinking, driving, or concentration tests that he finds it necessary to carry out.

It is foolish to scamp this work, for if it is properly carried out it is an insurance against the mistakes that are so often made by assuming facts before they are proved.

The causes of loss of capital are various. The chief cause is the attempt to work deposits which were too poor to pay, but were taken up owing to insufficient care being exercised in their original selection. Another cause is through the money being carelessly or ignorantly expended. Fluctuations of demand, excessive pumping charges, climatic conditions, inaccessibility, and so forth, account for other failures.

The net result is that the general investing public have a rooted distrust of mining as an investment, and treat it either as something to keep clear of altogether, or as a speculative gamble.

At the same time, if we do not produce the minerals we need we shall have to buy them, for they are an absolute necessity to industrial life.

The question resolves itself into this: "How can we restore the confidence of the investor?" The answer is: "By greater care in the selection of mineral properties, and greater energy in working them."

If one examines the history and the accounts of mines which pay regular dividends, it will be found that they are not always rich mines (in respect of the high percentage of metal in the ore), but that they have been well chosen in respect of local conditions and that the manager, staff, and directors are men who know their duties and carry them out with prudence and energy. In other words, the mines are worked in a *business-like manner*, and that is the main secret of their success.

Some fifty years ago it was easier to make mining successful. Wages were lower, and shallow, cheaply-worked deposits were available.

To-day working costs are higher, and many of the shallow, cheaply-worked deposits are exhausted.

It is, therefore, all the more necessary (1) to use minute care in the selection of properties ; and (2) to secure the best men to work them.

After a property has been found that shows promising features, and has been reported on and tested, it should, if possible, be worked on a small scale, with simple and inexpensive plant, before a large outlay is incurred. If this can be done so that a profit is earned, it will make it easier to sell the property, or to obtain finance to work it on a larger scale.

It has already been explained that different deposits have different risks attached to them. There is practically no risk of capital loss in the case of an alluvial property after it has been fully tested, and provided the local conditions are satisfactory.

On the other hand, one cannot test a lode property except by considerable expenditure of time and money, and until this time and money have been spent we cannot tell whether the expenditure will result in profit or loss. There is, therefore, a risk attached to the proving of lode deposits, which is greater than in the case of alluvial. Also, in most cases, a lode property will need a larger working capital.

Finance in the initial stages of testing a property is generally more difficult to obtain, because the value of the property is highly problematical. If the information collected during the testing results in proving the existence of payable ore, the property begins to have a real value.

Finance companies usually expect that properties offered to them shall have already been tested, or at least sufficiently opened up for their engineer to be able to examine them. The original discoverer or owner must not expect to receive any attention unless he has some definite values in sight or proved. Therefore, in the first case, he may have to depend on his own resources for the necessary exploration, or he may be able to form a syndicate with a few friends.

In such a case he should get an agreement drawn out legally, so that there can be no question of the relative rights of the parties interested.

Company Law.

As most mining undertakings require more capital than can be supplied by two or three individuals, it is customary to form a company.

This is done by preparing an application on the prescribed forms, and registering them (signed by seven individuals) at Somerset House. The name and object of the company must be stated, the nominal capital, and the number of shares into which it is divided. A memorandum and articles of association must be prepared, setting out the objects of the company, and defining its intended activities. Until the company is registered, and the fees paid, it is not permissible to make an appeal to the public for funds.

The prospectus must state how the shares are to be paid for ; it is usual for a portion of the purchase money to be sent with the application form. The directors allot the shares ; if applications are made for more shares than can be allotted, they may allot to each applicant a portion of the number they applied for. The balance due on the shares is required to be paid at stated dates, or may be left to be called up at the directors' discretion.

Under the Companies Act shares may be of different kinds, and a not unusual practice is to issue a portion of the capital in the shape of deferred shares, generally of small face value. These shares are nearly always issued to the promoters or vendors, and frequently confer the right to a large proportion of the profits in case the mine is a success, and carry with them a preponderance of

voting rights. The object of these issues is that the promoters and their friends shall retain the control of the company and secure the bulk of the profits, while the public find the money and take the risk. Such flotations are better avoided. The investor in such a company does not get a fair run for his money.

A more legitimate practice is the issue of preference shares. This is generally resorted to as a means of raising fresh money when unforeseen difficulties arise. The ordinary shares in such cases will, as a rule, be below their face value, and no one will take up fresh shares of the same kind for par. It is necessary, therefore, in order to procure new money, to offer the persons who are to find it either better security or a higher rate of profit, or both.

As a last resort the boards of unsuccessful companies sometimes issue debentures. These are better avoided by the investor, who is apt to be misled by the name and to think that a debenture must be safe.

It must be borne in mind that an unsuccessful mine has little or no sale value apart from the plant and machinery, and these as a rule will only fetch a small proportion of their book value.

Investors should bear in mind that the directors and employees of mining companies are apt to carry them on when there is no reasonable chance of success, in order that they may draw their fees and salaries as long as possible. In many cases they deceive themselves as to the chance of recovery, for men are apt to believe what it is their interest to believe. But because they deceive themselves, there is no reason why they should deceive the public, who as a general rule will be well advised to leave mining debentures severely alone. If the shareholders choose to put up fresh money, as a means of saving some part of what they have already ventured, that may be a different matter ; but even they should consider carefully whether it is not a case of throwing good money after bad.

Mining as an Investment.

The aim of this book throughout is to show how mining must be conducted in order that it may be made profitable.

It is very easy to waste money in mining; to earn it requires the exercise of good judgment and some experience. While the actual operations of mining are the business of miners, mining engineers and directors, the real arbiter of the fate of the industry is the investing public, that is, the shareholder, actual and potential. I suppose shareholders in mines seldom either visit mines or read books on mining.

But it is a basic industry of very real importance to every civilized country, and if investors will take some pains to distinguish between *legitimate mining enterprises and wild-cat propositions*, it will result in advantage to them and to the industry.

By legitimate enterprises I mean those that have been selected on logical grounds from carefully verified data, are capitalized on equitable lines, and are superintended by men whose experience and character are known to be good.

It is generally possible, on reading a mining prospectus or a report on a mine, to get a good idea of the capability and experience of those who are responsible for the statements contained in it, by examining the data that are given, the calculations or estimates, and the statements put forward as to future prospects.

To make a mining undertaking worth investing in, there must be clear evidence that minerals exist in sufficient quantity to be worth working, and under such conditions that their extraction will leave a large margin over the whole of the costs involved in extracting, preparing, and selling them.

The investor should carefully study a prospectus before deciding whether or not to invest in a new mining undertaking. In the case of mines that have been working for some years, and have large proved reserves, the risk of capital loss is less than in many other industrial businesses.

An investor may put money into a mine for two reasons: either to increase his capital by selling out again as soon as there is a rise in the value of the shares, or to hold shares on which he believes large dividends can be paid. In the case of an *established* mine which possesses reserves of known value, the price of the shares is not likely to fluctuate very much, but a regular dividend is practically assured, and the shares are always saleable; while in the

case of a mine in the *initial* stages, the value of the shares may rise or fall considerably as the ground is opened up, and they are much more speculative.

Some people are fond of a gamble, but even so they should read reports and prospectuses with a critical eye, in order to see that if they *do* gamble they have a fair chance of winning.

1. A prospectus should state clearly what the project is which it is intended to carry out, and how the money asked for is to be applied, and give sufficient details of the way it is intended to be spent, and show there is good reason to believe that the sum asked for will accomplish the end aimed at. It is most important to consider whether the working capital asked for is likely to be sufficient for the work required to be done, for if unforeseen difficulties and expenses arise, further money may be very difficult to obtain, and the original investors may be forced to put up more money than they intended, or be left in a position of stalemate and have to raise money on a debenture, which leaves them with a heavy debt to pay off before they can benefit by their first outlay, and in the meantime their shares are earning nothing and may be unsaleable.

2. The nature and extent of the property must be clearly stated and should be verified by independent persons, who have made a critical examination of the title deeds, licences or leases, the rents, royalties, taxes, export duties, and restrictions being clearly set out.

3. In all new ventures original reports should be furnished, showing the nature of the mineral and the extent of the lode or alluvial ground, and the percentage of minerals present, and how the samples were taken and examined when this was done, and by whom.

4. The methods of mining and dressing, the plant and staff required, should be given in detail, with evidence that the mineral is capable of being prepared or dressed up to a marketable condition by well-known and tested means.

5. The cost of mining, dressing, transport, and sale of the mineral should be shown, and the price it is expected to realize, and the quantity that the plant is intended to treat, so that the calculations of profit and loss can be

examined and compared with the costs of mining and realizing on similar ores in other parts of the world.

6. Exaggerated statements and vague suggestions of large profits sometimes appear in reports instead of clear statements of facts. Where these occur they should be sufficient to make the investor wary, for a competent mining engineer will not report in favour of a project unless he has proper facts to go on, and he will state these facts to show how his calculations are prepared from them.

7. As has been pointed out frequently in this book, some mining enterprises are from their nature much safer than others, and an inexperienced investor should begin by investing in these rather than in those which are more risky.

An adit proposition with adequate water-power is a safer thing than a shaft mine without water-power, and an alluvial proposition, commanded by water under gravitation, is safer than one where water has to be pumped, or where the deposit is below the natural water level.

8. Most losses of capital occur through selecting useless properties to work, which either contain no mineral worth speaking of, or are too expensive to pay. These losses can be avoided if directors and shareholders are careful to have properties examined by conscientious and experienced mining engineers. The time has passed for "taking chances," or plunging into "lucky tubs," and those who invest without investigation deserve to lose their money. Mining, if conducted by experienced men, on common-sense lines, need seldom result in a capital loss. Returns may be low during periods of low prices, but with competent people in charge of carefully selected properties, a good return on money invested in mining is not only *possible*, but can be made the general result.

When directors and shareholders take a keener interest, and educate themselves to distinguish the true from the false, avoidable losses will be diminished, and the industry will be brought into a healthy and vigorous condition.

CHAPTER XIII

Historical mentions of tin—References by Homer, the Book of Ezekiel, Herodotus, Polybius, Caesar, Diodorus, Pliny, Strabo—Institution of a Stannary Court—The "Perambulations of Dartmoor"—Cliff workings on the Cornish coast—Bauer's description of stamper mills—Position of Cornish mining in Elizabeth's time—Petition presented to the King in 1697—First steam pumping engine—Great County Adit—Borlase on "The Antiquities of Cornwall"—Pryce's Mineralogia Cornubiensis—The quantity and quality of ore worked in his time, and method of conducting the "essay"—His figures go to show that low grade ore was not worked—Earliest records of mineral production—Introduction of air-drills—Fall in price of tin owing to discoveries abroad—Hunt's "British Mining"

The decline of tin mining in Cornwall is due not to exhaustion, but owing to foreign competition from 1880 to recent years. Now there is every reason to expect a recovery, as the price is high and likely to remain so.

Before considering the history of tin mining in the West of England, it will be of interest to notice some of the early mentions of tin, and its uses at different dates.

It is probable that tin was one of the first metals to be discovered, seeing that alluvial tin would have been present in quantity in the beds of streams in mineralized districts, and that it can be reduced to metal by a hot fire of dry wood. It is difficult to see what use metallic tin by itself would be to primitive man, but as soon as he discovered that by alloying copper with it he could make tools and weapons with a good cutting edge, he would attach a very high value to it.

The earliest tools and weapons were made of stone, then came tools and weapons made of copper. Copper can be hardened to some extent by hammering and tempering, but a bronze made with about 90 parts of copper and 10 parts of tin, makes a much better material. Bronze is very resistant to the action of air and moisture, so that some of these ancient implements have remained to be discovered many centuries after they were made. In addition, we have written records which mention the trade in tin and the uses to which it was put.

The following list of mentions is by no means complete, but it will serve to show what a remarkable influence this metal has had on our history. The fact that this country

was the principal one where tin was known to occur in ancient times, brought traders to our shores, and stimulated us to become a seafaring nation. The need for draining our mines was the direct cause of the invention of the steam-pumping engine, and the experience gained in mining for tin and copper has enabled us to supply miners to all parts of the world.

To come now to records of the past.

During excavations carried out by the antiquarian Flinders Petrie, at the ruins of the ancient city of Meydum, a rod of bronze was found containing 90 per cent of copper and 10 per cent of tin, which was estimated by him to have a date of about 3500 B.C.

1200 B.C. is the date assigned to the siege of Troy, in the description of which mention is made of a breastplate of bronze.

Robert Hunt, after quoting many authorities, says: "An examination of all that has been written on this subject . . . leads one to the conclusion that at least 1200 B.C. the Phoenicians, sailing round the coasts of Spain found that tin could be obtained there, and established trading stations at Gades (the modern Cadiz). Having established this trade, these adventurous navigators began to explore the coasts of countries farther north, and eventually discovered the Tin Islands, or Cassiterides."

800 B.C. The poet Homer, writing about this date, refers to the bronze armour used at the siege of Troy.

600 B.C. In the Book of Ezekiel tin is mentioned as one of the articles of trade at Tarshish.

500 B.C. Roman and other bronze coins of this date have been found.

440 B.C. Herodotus, the Greek historian, stated that he was not able to ascertain the exact position of the Cassiterides, but that there was no doubt that the supplies of tin came from thence.

340 B.C. *The Voyage of Scylax* mentions colonies of the Phoenicians on the coast of Spain, where they had factories and trading stations.

200 B.C. Polybius, a Greek historian, described the extraction and smelting of tin; his work as a whole is lost, but he is quoted by Strabo and other writers.

55 B.C. Julius Caesar mentions tin; the expectation of finding mineral wealth in Britain was one of the reasons that induced the Romans to undertake the conquest of Britain.

8 B.C. Diodorus Siculus, writing eight years before the Christian era, states that: "The inhabitants of Britain, in that extremity of the island called Bolerion (the Land's End) excel in hospitality, and by reason of their intercourse with foreign merchants are civilized in their mode of life. These prepare the tin, working very skilfully in the earth which produces it. The ground is rocky, but has in it earthy veins, the produce of which is brought down and smelted. Then when they have cast it into the form of cubes they carry it to a certain island adjoining to Britain, called Iktis. During the recess of the tide, the intervening space is left dry, and they carry over abundance of tin in their carts . . . from here, then, the traders purchase the tin of the natives, transport it to Gaul (France) and finally travelling through Gaul on foot in about thirty days they bring their burdens on horses to the mouth of the river Rhone." This gives us a clear picture of the trade in tin in Roman times. Diodorus goes on to say that at the capture of the town of Alesia (the modern Arras) in Gaul it was found that the coppersmiths there possessed the art of tinning the inside of copper vessels. At the present day the saucepans used in French homes are generally made of copper and tinned inside.

The island "Iktis," mentioned above, is believed to be St. Michael's Mount, which is an island except at low tide. It would seem quite natural that the early inhabitants of Cornwall should take their tin to this point, as in trading with comparative strangers they may not have desired them to come inland.

A.D. 79. Pliny, the Roman naturalist, mentions that tin was found in stream-beds in the form of black pebbles in Spain. It is not clear from his description whether he knew that it came from England also.

During the Roman occupation it is probable that tin was worked by the inhabitants under the compulsion of their conquerors.

The chief uses of the metal at this time would have

been to make bronze for tools, weapons and ornaments, for the tinning of copper vessels, and for making pewter. Supplies of copper at this period did not come from Britain, but copper mining had been for a long time very actively carried out in the island of Cyprus and in Arabia, so that there was plenty of copper available to use with tin for the manufacture of bronze. The Roman occupation of Britain terminated about A.D. 300; during this time they had made roads, so that communication and trade must have been growing. Strabo, a Roman writer, speaking of the trade in tin, says: "Formerly the Phoenicians alone carried on this trade from Gades."

A.D. 500. About this date bells began to be used in churches; the proportion of tin used in bells was about 25 per cent.

A.D. 950. In the reign of Athelstan a Stannary Court was set up; dues were paid to the Sovereign on all tin mined.

A.D. 1209. King John gave a charter to the tinners.

In a document of about this date, called the "Perambulations of Dartmoor," a mention is made of *Furnum Regis*. It seems possible that this may be identical with the ruin known as "King's Oven," close to Warren Inn, between Princetown and Moretonhampstead.

This place, King's Oven, has been partly destroyed during the past thirty years, but its ruins still exist. It is supposed to be one of the old "blowing houses," of which there are traces in many parts of Devon.

A.D. 1240. At this date the West of England was the principal source of supply of tin to the whole of Europe.

A.D. 1305. King Edward I confirmed the charter given to the tinners by King John.

A.D. 1337. Edward III organized the Stannary Court more satisfactorily, and extended the tinners' rights.

A.D. 1550. Up to this time the greater part of the tin seems to have come from alluvial workings; as these became less productive, the outcrops in the cliffs attracted attention, and cliff mining began about this date. It developed considerably during the seventeenth century, and continued through the eighteenth century. It may be regarded as bridging the period between alluvial

mining, which was diminishing, and underground mining which was in its early stages.

Cliff workings are particularly noticeable in the districts of St. Just, St. Agnes, and Perranporth. Adit mining was known to, and practised by, the Romans centuries before, but it is probable that the convenience of cliff workings, as being self-draining, made the use of adits popular. Cliff mining came into use not only for winning tin, but in working for copper and silver-lead.

A.D. 1509. In the reign of Henry VII the importation of tin from abroad was forbidden in order to protect the home industry. At this time the yearly production in the West was about 450 tons.

The only other production in Europe at this time was in Bohemia, Saxony, and Spain, and is believed to have been very small.

A.D. 1546. "Georgius Agricola" (whose real name was Bauer) published his work on the metal industry, *De Re Metallica*, at Basle. He described stamper mills which had been at work in Germany as far back as 1400, but were not introduced into England until many years later. The mill he describes is very similar to one or two which can still be seen working to-day, the stems being wooden balks with cast-iron shoes.

A.D. 1583. Copper was being mined and smelted in a small way at Perranzabulo. From this time onward to about 1850 copper mining was active, though it did not attain importance till 1700.

The general average produce of the copper mines of the West was from 7 to 8 per cent copper. During the above-named period, copper mining and tin mining were proceeding side by side, in many cases both minerals were being raised from the same mine. Tin lodes often carry their mineral right up to surface, whereas copper has seldom been found outcropping. As a rule, the copper-bearing zone is from a few fathoms below surface down to 100 or 150 fathoms, then in many cases tin is found below.

A.D. 1570. In Queen Elizabeth's time a number of German miners were sent for to assist in improving our mining methods. The production of tin at this time was about 1,400 tons a year. Sir Walter Raleigh was at one time Lord Warden of the Stannaries, and Member of

Parliament for Mitchell. Answering some criticism in Parliament, he declared that he had been the means of improving the position of the tinners, and that the measures he had introduced had raised their pay from 2s. to 4s. a week.

A.D. 1602. Carew gives a description representing the methods employed in the treatment of tin ores in 1602. Carew mentions stamper mills driven by water wheels, the stems being logs of wood shod with iron. After the current of stamped ore had flowed out of the mill, it was caused to flow in a series of falls on to turfs, to retain the mineral. He describes the stamp attendant stirring up the sand, so that the lighter waste may be carried off by the water, while the heavier tin remains fast on the turf. As an improvement on this, he states that in some cases boys were employed to stir up the sands with their feet, which produced the same effect of ridding the tin concentrate of the waste sand. The further cleaning of the concentrate was accomplished by "shogging" (shaking or jigging) it in water, in a pan 2 ft. wide, held by two handles.

A.D. 1620. While the tinning of the inside of copper vessels was practised in Roman times, if not earlier, we have no account of the tinning of iron until this date, when it was an industry in Bohemia.

In 1625 an Englishman named Yarranton visited Bohemia, to inquire into the industry and learn the methods employed. He was well received and given information, and on his return he succeeded in making many parcels of tinplate, which were found satisfactory by persons in the habit of using the German plate. In spite of this, nothing appears to have been done to establish a manufacture of tinplate in England for a whole century.

A.D. 1670. German miners introduced blasting into England; up to this date it had been customary to use the ancient method of fire-setting (building a fire to heat the rock and throwing water on it while hot), when very hard rock was encountered.

A.D. 1671. A paper was read before the Royal Society which is quoted by Hunt. The details he gives indicate that mining was in a very primitive state, being mostly

confined to open cast workings, and the ore was manhandled by shovelling it up from one stage to another ("shammelling").

A.D. 1697. A petition was presented to the King and Houses of Parliament, setting forth the difficulties of the tinners owing to the extremely low price of tin at this date. The petition explains how the Venetians, by taking certain measures, restored their trade in wine and currants, which had been nearly ruined by smuggling. It states that some years before the Restoration, the tinners received £6 5s. a hundredweight for their tin, and reckons that the income received by the sale of tin was £200,000 a year, but that since then the selling side of the industry had been so mismanaged, that while the quantity sold was much the same, the price had fallen to £2 10s. a hundredweight. The petition proposed a tax on all persons buying or selling below a price to be fixed, and showed that the very low price then prevailing was checking production, as it was quite impossible for the tinners to go on producing at such low rates.

The petition also gave an interesting calculation of the cost of timber, rope, candles, and smith's work in proportion to the tin produced. (Owing to the great difference in money values to-day, it is impossible to make a real comparison of costs.) This petition states that some 8,000 miners were "partly employed," probably they were partly employed in growing their food, as it seems that they could not have lived on what they made by the sale of tin only. At the date this petition was presented, one-fifth of the value of the tin raised was paid out in royalties and dues. The petition states that the West of England was the only producer, except that small quantities of tin were raised in Germany and the East Indies, and that these countries could not afford to sell under £5 a hundredweight, so that a rise of price would not check sales, as tin was a necessity all over the world.

A.D. 1700. Copper mining had been going on in a small way since 1483, and at this date began to be of greater importance. During Queen Anne's reign, 1700 to 1714, tin was produced more rapidly than the market could absorb it. The normal home consumption at this date was about 1,000 tons a year; the amount exported was

nearly 2,000 tons. It is said that there was at one time a stock in hand equal to five years' consumption.

The increasing depth of the mines, and the quantity of water that had to be pumped, was becoming a serious difficulty to the miners.

A.D. 1712. At this date the first steam pumping engine was set to work at Wheal Vor. (No steam engines seem to have been used for stamping until many years afterwards.)

A.D. 1729. The tinplate industry was established successfully in Wales; by the year 1776 the works in Wales were exporting tinplate all over the world.

A.D. 1733. Thomas Tonkin stated that fire-setting was still frequently employed to assist in getting through very hard rock.

A.D. 1748. The Great County Adit was begun by Capt. Williams, then manager of Poldice Mine. The farthest mine it connects with is Cardew, five-and-a-half miles from its mouth, which is at Bissoe in the Carnon Valley. With all its branches it is nearly thirty miles long. It took over twenty years to complete, and was driven at a time when there were neither high explosives nor compressed air to assist the miners. Although it must have been a costly undertaking, it answered its purpose, which was to relieve a large group of mines from part of their pumping charges. By pumping to adit level, instead of to surface, they saved £19,000 a year.

A.D. 1750. From this date to 1854 the average production of tin in the West was 3,000 tons a year. Yearly records have been kept since 1750.

A.D. 1756. Dr. Borlase (Vicar of St. Just for twenty-four years) published his work, *The Antiquities of Cornwall*. Writing of the ancient trade in tin, he says: "If the Phoenicians in their northern voyages coasted along the shores of Spain and Gaul (as was doubtless the most ancient way of navigating) then the shores of Britain opposite to Gaul must certainly have been known to them; but at whatever part of our Island they first arrived, the western parts certainly had the greatest share of their commerce, if not the whole. The Phoenician business into these parts was not conquest or glory, but trade; and from Gades they traded to Britain bringing salt,

FIG. 14. DRESSING CONCENTRATES ON THE DREDGE LAUNDERS
(Tavoy Tin Dredging Corporation)

crockery and brazen ware. What they came for was tin, lead and skins, but especially the former, which was found to be so useful a metal that it grew famous all over the then known world, and encouraged the Phoenicians to continue and engross the trade to this Island. . . . Tin was also found in Spain and Portugal but in too small quantities to satisfy the expectations of so many cities and countries as were desirous to have it."

Dr. Borlase gives a very good account of the method of searching for tin lodes. He says that it was the common practice to trace lodes by the scattered fragments of them, called " shodes," and describes the process of sinking " costean," or trial trenches, in a systematic manner to ascertain the exact position of a lode. He also gives a clear account of the stream works existing in his day.

A.D. 1767. At this date there were eighteen pumping engines at work in Cornwall, but there is no mention of any engines being used to run stamps.

A.D. 1778. William Pryce, a doctor of Redruth, published his book, *Mineralogia Cornubiensis*. This is a most valuable work, as it gives a very clear account of the position of the industry at that date. The appliances in general use are both described and illustrated. From various figures that he gives, we are able to get a good idea of the quality of the ore raised at that period. There is so much information of all kinds in Pryce's book, that one cannot convey any idea of its value by a few quotations, but the following will show that it deserves careful study by those who wish to acquaint themselves with the state of mining at that time. As regards general mining methods, he says : " I do not suppose the present methods for working tin mines by deep shafts, and by driving and stopeing under the firm ground, has been practiced for more than three hundred years past. Prior to those means for raising of tin. they wrought a vein from the bryle to the depth of eight or ten fathoms, all open to grass, very much like the fosse of an intrenchment. This was performed by the dint of meer labour, when men worked for one-third of the wages they now have."

Pryce goes on to explain that the lodes were formerly worked by the method of " shammelling," that is, opening a trench and digging down in terraces or steps. The

broken ore was shovelled up from each terrace to the one above it. The word "shammel" seems to mean a stage or platform, and "shammelling" was the act of transferring the ore from the bottom of the working to the surface by shovelling it up from stage to stage. Stamper mills were introduced about 1598, in Queen Elizabeth's reign, and consisted of ash logs with an iron stamp-head. The weight of the stamp in Pryce's time was 170 lb.; to-day the head and lifter of a Cornish stamp is about 6 cwt., and three or four times as much in modern patterns.

Pryce describes methods of dressing which are very similar to those used to-day, except that in his time there were no shaking tables, vanner belts, or ragging frames. Probably the greater part of the slime tin was lost.

As regards smelting, he states that black tin was sold to the smelter by sample. Previous to this it was customary to hire a "blowing house" at a cost of 20s. for a "tide," or period of twelve hours. In 1778 both "blowing houses" and reverberatory furnaces were at work. A blowing house contained the cupola, or furnace, which was 6 ft. high and $2\frac{1}{2}$ ft. wide. The air was supplied by a pair of bellows 8 ft. long and $2\frac{1}{2}$ ft. wide, the nozzles of which entered the furnace 14 in. above the bottom. The ore and fuel (charcoal was used at that time) were laid in layers. He states that good stream tin ore produced 14 cwt. of metal from 20 cwt. of ore, that is, the yield was 70 per cent, and that "grain tin" (metal produced from stream tin smelted with charcoal at a blowing house) fetched more money than mine concentrates smelted with coal in a reverberatory furnace.

Pryce is enthusiastic on the importance of adits, and says that they were driven to unwater mines: "By which means . . . many more valuable lodes have been discovered than those they were driving to unwater."

He gives a good account of the method of testing the value of ore by vanning on a special shovel, and describes three qualities of ore: "not rich," "average," and "good tin stuff."

He describes first the "rough essay," in which a "handful" of powdered ore is taken; but points out that a more accurate method is to take "half a wine pint,"

and to weigh the concentrate in penny-weights and grain weights on a balance, such as is used for weighing money. In the absence of a balance he gives a method of estimating the value of a "van," by the space the black tin will cover.

For instance, a "shilling van" is where the concentrate obtained in vanning will cover a shilling. This, he says, indicates a yield of 1 cwt. of metallic tin obtained from 100 "sacks" of hand-picked ore, and describes it as "not rich" (it would correspond to a recovery of over 1·2 per cent of black tin).

He describes a "crown van" as the quantity of clean concentrate obtained from half a pint of ore, which will cover a crown piece, and calls this "good tin stuff." He states that such ore will give 5 cwt. of metal per 100 sacks. Working this out, we find that ore of this quality would give a recovery of 5·7 per cent of black tin (100 "sacks" was equal to 125 cwt.).

But perhaps his most interesting and important statement is that the ore mined in his time *averaged* 2·4 per cent of metal.

This corresponds to a recovery of over 3·4 per cent of black tin per ton. The total production of metallic tin in the West, at the time he wrote, was 3,000 tons of metal tin per year. As we cannot suppose that the recovery was as efficient in his day as it is now, it is clear that the ore then mined contained a high proportion of black tin; on similar ore to-day we should get a higher recovery.

This is due to the use of modern slime plant, and to the regrinding of the rough tailings. If we admit that 30 per cent of black tin is lost to-day in the process of dressing, we may consider it probable that the former losses were over 40 per cent. From this we see that the ores mined in his time, and from which as he tells us ·8 per cent, 2·4 per cent, and 4 per cent of *metal* were obtained, must have contained 1·7, 5·6, and 9·5 per cent of black tin!

In all these figures no account is taken of loss in smelting.

This goes to show that the miners at that time worked on the richest ore only, which we might naturally expect, as it would hardly have paid them to work on ores that we should consider good to-day.

Pryce states that 126,000 tons of ore were raised and stamped to produce 3,000 tons of tin (metal).

They left alone as far as possible low-grade and complex ores. There are several reasons for this; they had no compressed air nor high explosives to assist them, and they had but small facilities for pumping, as the steam engine was not in general use. In addition, stamping was all done by little mills worked by water-power, some of which would be partly hung up in summer for want of water.

In an instance that he gives of the result of working a stope on tribute, he shows that the royalty paid was one-third of the total value, whereas to-day it is about 3 or 4 per cent, and that the price of the metal was only then £3 a hundredweight, while to-day it is worth five times as much!

In A.D. 1778 Thomas Curtis, a poor miner of the parish of Breage, started work on the "Wherry Mine" at Penzance. He had observed at low tide a rich lode, which crossed a rock that was submerged for the greater part of the 24 hours. He built a wooden shaft on this rock and secured it with bars of iron, and caulked it to keep out the water. It was only possible to work on the rock in good weather, and then only for a few hours at a time. The story of his resourcefulness is told by Robert Hunt. Ore to the value of £70,000 was eventually raised from this mine. Part of the ore was tin pyrites, and the ore was roasted to break up the sulphides and to make it easier to stamp. The enterprise eventually came to an end through a vessel breaking from its moorings, and demolishing the shaft.

In A.D. 1789 the East India Company began to export tin to China.

A.D. 1812. The first steam engine is believed to have been used for stamping ore at Wheal Vor. Prior to this all stamping had been done by water, and more than one writer has remarked on the difficulties caused by the shortage of water in summer.

A.D. 1806. John Taylor constructed a pair of crushing rolls at Crowndale Mine, near Tavistock. Brunton's calciner came into use about this date.

A.D. 1820. Banca tin was being imported into England. In 1829 *Records of Mining* were published by John Taylor.

Hunt says that in 1830 it was not an unusual sight to see trains of pack-mules carrying ore to the stamps, or black tin to the smelting houses.

In 1834 iron lifters were used at Lanescot Mine instead of ash logs.

In 1837 the *Mining Review* first appeared ; it contained many special articles on mining districts in the West.

In 1836 an interesting report, by a Mr. Wicksteed, was published in the first volume of the *Transactions of the Institute of Civil Engineers.* He visited Cornwall on behalf of the directors of the East London Water Works, who could hardly believe the good account they had heard of the performances of Cornish pumping engines.

He says : " I saw at Redmoor an engine with a 50 in. cylinder, erected by Messrs. Petherick and West. . . . The engine was working about two strokes a minute throughout the 24 hours ; the work done was light, probably not equal to more than five horses' power ; it consumed only three-and-a-third imperial bushels of coal per 24 hours ; the engine had worked the previous fortnight with turf cut off the neighbouring moor, at a cost of eightpence-halfpenny per 24 hours. Eighteen square feet of turf were used two inches thick." On another page the writer states that the " bushel " is 84 lb. of coal. He also mentions seeing at Fowey Consols " a most splendid engine " (an 80 in. cylinder) ; " it does more duty than any other engine in Cornwall," and states that it was consuming one bushel of coal an hour.

In 1837 there were 57 mines at work in the West producing black tin, which was valued at £47 10s. per ton. In the following year the Council of the British Association passed a resolution, recommending the keeping of records of mining operations. In this year Sir Charles Lemon offered to start a mining school in Cornwall.

In 1840 the Mining Record Office was established. It was placed in charge of Sir Henry de la Beche, and Thomas Jordan was appointed Keeper of the Records. In 1845 Robert Hunt succeeded Jordan, and began to collect statistics of the production of mines all over England.

In 1844 Brunton proposed the working of drills by compressed air. About this time Oxland, of Plymouth,

introduced his process for the removal of wolfram from tin ore by roasting with soda ash.

In 1851 the Royal School of Mines and the Museum of Practical Geology were opened. At the Museum there is a very fine collection of minerals, and visitors can see geological maps with the most recent observations collected by the Survey.

In 1857 James Henderson read a paper on "Ore Dressing in Cornwall" before the Institution of Civil Engineers; this paper was accompanied by excellent illustrations.

In the same year M. Moissenet, of the School of Mines, of Paris, visited Cornwall, and described the processes in use and gave 45 illustrations of the apparatus employed. In the following year Blake, of America, invented the rock breaker, which with very little alteration is used everywhere to-day.

A.D. 1861. For some years experiments had been going on to use compressed air for drilling; in this year drilling was begun with Sommeillier's air drills at the Mont Cenis Tunnel.

In 1865 there were 156 mines (some of them very small), producing 14,122 tons of black tin. The price of black tin was £55 a ton, which must have been very close to, if not under, the cost of production. The prices for the next three years were £48, £50, and £55.

In 1870 there were 147 mines at work, producing 15,234 tons of black tin, the price of which was £75 a ton. Tin was now beginning to be imported into England from Australia and elsewhere to such an extent that the market was unable to absorb it, and the result was disastrous to the home industry.

A.D. 1874. From this date on to 1886 the average price of black tin was less than £50 a ton, which was in many cases under the cost of production in Cornwall, and many mines had to close.

Looking at the price of metallic tin during this period, it would seem that the smelters did not pay for the black tin the price that the selling price of the metal appears to warrant; this may have been due to some of the ores being complex or, in the unsettled state of the market, the smelters may not have had a free or certain sale for the metal.

A.D. 1880. In this year the world's production of tin was 38,000 tons, of which Cornwall produced one-quarter; the remainder came in about equal amounts from the Dutch East Indies, the Malay States, and Australia. Wolfram was saleable at this date in small quantities, and fetched about £8 a ton. In the following year 95 mines in the West produced 12,898 tons of black tin.

In 1884 Robert Hunt's *British Mining* was published, and a second edition was issued three years later. In spite of the lapse of time, this is still a most useful book, not only from the historical point of view, but because of the sound common sense of the writer. It contains a wealth of information regarding mines not only in the West, but all over Great Britain. Hunt wrote at a time when the tin industry was being crippled by foreign competition, as well as being seriously weakened by faults which he points out.

At that period the outlook for Cornish mining was very black, for it is hardly possible that anyone at that date could have foreseen the enormous increase in the world's consumption of tin that exists to-day.

In 1885 tin began to come into England from Bolivia. The importation grew rapidly, and to-day Bolivia is one of the three chief producers.

In 1894 the world's production of tin was over double that of 1880, but instead of Cornwall producing one-fourth it contributed one-tenth.

After 1895 the Cornish production fell to between 4,000 and 5,000 tons, and only exceeded this on a few occasions.

Although the price of tin rose in 1899, it did not do so sufficiently to be of much assistance to the Cornish industry.

At the end of the war the Cornish mining industry almost came to a standstill; at the present time a revival is taking place.

There are now some eight or nine mines at work, and it will largely depend on the results obtained from them what support is given by investors in the near future.

If the price of tin remains above £250, there are many mining setts which will pay well to work. There is an impression among many people that the West of England mines are exhausted. This may be the case in one or

two instances, but it is certainly not true of the majority. The facts given in the earlier part of this chapter go to show that while mining has been carried on for a long period in Cornwall, the workings before 1800 were shallow, and only the richest ore was worked. Until air drills and high explosives were available, mining as we know it to-day was impossible ; it was performed, as Pryce puts it, " by the dint of meer labour," and very shortly after proper mining appliances were available, the industry was ruined by the discoveries abroad. To-day the case is altered ; the world can consume all the tin that can be produced, and the price is such as to leave a good margin of profit.

It is difficult, if not impossible, to get a figure which represents the working costs in Cornwall at the present day, but we may put them down as something like 27s. per ton of ore milled, in the case of a mine where there is a normal amount of pumping. In an adit mine the cost may be 5s. a ton less, as neither pumping nor hoisting is needed. There are many areas where it is known that there is payable ore and, if it is possible to gain the support of investors, there is nothing to prevent the industry from becoming greater and more prosperous than it has ever been in the past.

APPENDIX

THE following minerals have sometimes been mistaken for cassiterite, and their characters are given here to assist the reader in recognizing them.

Wolfram, tungstate of iron and manganese. It has usually a characteristic laminated or banded appearance and is black in colour, but sometimes is found in quartz in needle-like crystals, with a lustre that is more vitreous than usual and a reddish colour. The streak of wolfram is deep chocolate or brownish-red. The specific gravity is about 7·2, varying from 7 to 7·5, heated before the blow pipe it does not melt, but flies to pieces.

When very finely powdered and boiled for a long time with *aqua regia*, the iron and manganese dissolve, leaving the tungstic acid as a yellow powder, which is soluble in ammonia.

Wolfram is often associated with cassiterite, both in alluvial and in lodes.

Magnetite, oxide of iron. The colour is black, with either semi-metallic lustre or dull. The streak is black. The hardness is about 6 and the specific gravity is about 5. It is slightly fusible at the highest heat of the blow pipe. On boiling with hydrochloric acid. in fine powder, it is slowly dissolved. Tested in the borax bead it gives a bottle-green colour in the reducing flame, yellow in the oxidizing flame. It is attracted by a hand magnet.

Ilmenite, titanate of iron. The colour is dull black, sometimes with dull metallic lustre. The specific gravity is about 4·5 ; the hardness is about 5, but varies. The fracture is granular or conchoidal. It is unchanged on heating before the blow pipe. In a microcosmic bead it gives a deep purple-red in both oxidizing and reducing flames. The streak of ilmenite is black. It is easily decomposed by fusion with acid potassium sulphate. On boiling a piece of tin in the solution, obtained by dissolving the fused mass in hydrochloric acid, the brown colour disappears and a violet colour is produced.

Black Tourmaline, or schorl (also known as " Cockle," by miners), is black or blackish-brown. It is frequently found in tin lodes. The specific gravity is much lower than that of cassiterite, being about 3, the lustre is dull to vitreous. The streak is colourless. Black tourmaline is very often found in the pan when panning earth, sand, or powdered rock. It is much softer than cassiterite and easily washed away from it in the pan, or on the vanning shovel.

Tantalite. Tantalite of iron and manganese with some niobate of iron and manganese. This comparatively rare mineral is nearly black on a fresh fracture. Weathered specimens are dark reddish-brown on their exposed surfaces. It is hard ; the specific

gravity varies from 6·5 to 7·5, so that it has nearly the same gravity as cassiterite. The lustre is sub-metallic, and the streak a dark brownish-olive colour. Before the blow pipe it is unaltered and does not melt. It is insoluble in acids. It could not be mistaken for cassiterite on testing, as it gives no metallic bead with cyanide.

Blende. Sulphide of zinc, is usually brown in colour; it is also less frequently found black or yellow and sometimes nearly white. The lustre is usually vitreous or resinous, but sometimes semi-metallic. The gravity is about 4, the hardness is variable, from 3 to 4. Heated in an open tube, sulphurous fumes are given off.

Blende is soluble in warm hydrochloric acid; this distinguishes it at once from cassiterite.

Garnet. Red and brown garnets have been mistaken for cassiterite. Their specific gravity is between 3·5 and 4·3, and their hardness from 6·5 to 7·5; they melt before the blow pipe. They crystallize in the cubic system.

Recapitulation of the Tests for Cassiterite. It is quite impossible to identify cassiterite by its colour, which is very variable.

While *typical* cassiterite crystallizes in a tetragonal prism, terminated by a tetragonal pyramid, a great many specimens are not typical. Alluvial cassiterite is often a rounded gravel showing no crystalline form at all.

Again, the hardness cannot be relied on, for while well-formed crystals are too hard to scratch with a knife-blade, some cassiterite is quite brittle.

One cannot, therefore, rely on the above physical tests, or on the specific gravity, as several minerals have the same gravity.

The test with zinc dust and acid, described at the beginning of this book, is very quickly performed and trustworthy. It should be confirmed by the reduction of the mineral to metal, either before the blow pipe or in a crucible, with cyanide. If cyanide is not at hand, cassiterite can be reduced to metal by mixing it in fine powder with powdered charcoal, and strongly heating in a crucible on a smith's forge.

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